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Characterization of the Washington, D.C. Oxidant Problem

GCA Corp, Bedford, Mass GCA Technology Div

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This report describes the results of a study to characterize the oxidant problem in the Washington, D.C., metropolitan area. Emphasis is placed on ambient monitoring data on ozone, nitrogen oxides and nonmethane hydrocarbon concentrations observed during Summer, 1976. Additional data collected during the study and summarized in the report include: surface and upper air meteorological data, aircraft observations of O_3, NO, NO_x, SO_2, and condensation nuclei, and hydrocarbon species data. Both horizontal and vertical ozone profiles obtained during the two weeks of aircraft sampling in and around the Washington, D.C., area are presented. Results of trajectory studies, hydrocarbon composition analyses, and analyses of the ambient concentration data are summarized in numerous figures and tables. HC and NO_x emission inventories compiled by MWCOG are provided.

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CHARACTERIZATION OF THE WASHINGTON, D.C. OXIDANT PROBLEM

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CHARACTERIZATION OF THE WASHINGTON, D. C. OXIDANT PROBLEM

Final Report

by

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Contract No. 68-02-1376
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EPA Project Officer: Warren P. Freas

ENVIRONMENTAL PROTECTION AGENCY
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Research Triangle Park, North Carolina 27711

September 1977

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FOREWORD

As its first task under Contract No. 68-02-1376, Task Order No. 27, GCA/Technology Division was to evaluate the adequacy of the data base in the National Capitol AQCR for developing and testing techniques by which changes in VMT and/or vehicle emissions could be related to changes in ambient levels of oxidants and carbon monoxide. The data were to be drawn from a baseline summertime period in either 1973 or 1974 and the corresponding period in 1976. If the data base proved to be adequate, work in developing these techniques was to begin.

At the conclusion of this task it was jointly concluded by the EPA Project Officer and GCA/Technology Division that fundamental inadequacies in the existing data bases would prevent carrying out the development and testing of such techniques at this time. As a result of this decision, a more general study of the oxidant problem in the Washington, D.C. area was substituted for this phase of the work. The results of this general study are presented in this report. Weekly reporting of oxidant levels and current traffic, visitor, and meteorological statistics that might relate to these levels was carried out for the Bicentennial summer season as scheduled in the original scope of work.

Under a CO phase of the program, relationships between traffic, vehicle emissions, and CO levels within the Washington, D.C. area were analyzed using revised CO Hot Spot Guideline techniques and supplementary computer simulation models. The results of this work are provided in a separate report.

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- Department of Environmental Protection, Montgomery County, Maryland
- Alexandria Health Department, Alexandria, Virginia
- State Air Board, Northern Virginia Office

We would also like to thank the Office of Environmental Quality of the Federal Aviation Administration for providing air quality data collected during the Concorde Monitoring Program at Dulles International Airport, and EPA's Environmental Monitoring and Support Laboratory — Las Vegas for its cooperation in supplying the Aerial Oxidant Survey data.

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EXECUTIVE SUMMARY

INTRODUCTION

This report documents the magnitude of the measured oxidant problem in Washington, D.C. and environs and analyzes data from the summer study conducted by EPA in 1976 to better define the relationship between oxidant concentrations and precursor emissions. The Washington, D.C. area was selected for study partly because of its known oxidant problem, and partly because of the possibility that an influx of summertime visitors during the Bicentennial Year might result in a clearly definable increase in oxidant levels which could be associated with a measured increase in vehicular travel.

After a review of existing data it was estimated that the maximum increase in areawide VMT likely to occur between the summers of 1973 and 1976 was 10 percent. The possibility of detecting the effect of such a small change in VMT on observed oxidant levels in view of the large variations that occur from year to year as a result of differences in meteorological conditions was considered to be extremely small. In addition, the available traffic data were inadequate to define areawide changes in VMT for comparison with oxidant levels on a daily basis. As a result, the emphasis of the work was shifted from an analysis of the effect of changes in VMT on observed air quality to a characterization of the oxidant problem in the area.

DATA ANALYZED

The various summaries and analyses presented in this report are based on the following sets of data, some of which were obtained from the regularly operated surface networks and ongoing activities, and some from special measurement programs.

Emission Inventory Data

HC and NO_x emission inventory data were provided by the Metropolitan Washington Council of Governments for the base year 1973. Area source emissions for HC and NO_x were furnished for each of the 145 Policy Analysis Districts in the Washington metropolitan region, and a point source emission inventory was provided for the major NO_x sources.

Routine Surface Network Data

Local agencies supplied ozone and other gaseous pollutant data of interest at 18 sites of which 7 were in Washington, D.C., 5 were in Maryland, and 6 were in Virginia. Also, observations made at two stations in the vicinity of Dulles International Airport during the summer period as part of a program to monitor operations of the Concorde airplane were made available by the Federal Aviation Administration. As part of the summer program, EPA's Environmental Monitoring and Support Laboratory conducted a quality assurance program of the monitoring networks.

Meteorological Data

The surface meteorological data used in the analysis consisted of climatological data from National and Dulles International Airports, wind speed and direction from eight local agency sites in Virginia and Maryland, and solar radiation data from the Alexandria Health Department site. In addition to the two regular upper air soundings which are made daily at

Sterling, Virginia, one additional sounding per day was made during July and August in support of the summer program.

Traffic Count Data

Daily traffic volume data were supplied by the Washington Department of Transportation, through the Council of Governments, for the following three sites: (1) Memorial Bridge, (2) Anacostia Freeway at Howard, and (3) South Capitol Street Bridge.

Special THC, CH_4, NMHC, and CO Observations

Ambient concentrations of total hydrocarbons, methane, nonmethane hydrocarbons and carbon monoxide were measured at six sites by Research Triangle Institute. Integrated concentrations over 3-hourly periods from 0600 to 1800 EDT were obtained on a daily basis from July 3, 1976 through September 1, 1976. The six sites were the West End Library and CAMP sites in Washington, D.C., the Fairfax and Alexandria sites in Virginia, and the Bethesda and Suitland sites in Maryland.

Detailed HC Composition Data

Ten percent of the grab samples described above were analyzed routinely by RTI for the following hydrocarbons:

- ethane and ethylene
- acetylene
- propane
- propylene
- isobutane
- n-butane
- 1-butene
- isopentane
- cyclopentane
- n-pentane
- toluene

Aircraft Observations

Concentrations of O_3, NO, NO_x, SO_2 and condensation nuclei were measured by the EPA Air Quality Branch of the Environmental Monitoring and Support Laboratory-Las Vegas during 16 flights from August 17, 1976 through August 27, 1976. The flight patterns began as approximate circles around the perimeter of the Washington Tower Control Area, but evolved into longer flights to investigate conditions during a stagnation period which developed during the program. One or more spiral soundings were usually made during each flight.

DATA ANALYSIS

Summary figures and tables based on data from the 20 monitoring stations are presented to show the geographical extent and magnitude of the oxidant problem. Emphasis is placed on the maximum hourly ozone concentration observed daily at each station, the time of day when this maximum occurred, and the frequency with which the standard was violated. Other features of the ozone concentration field that are discussed include its relationship to meteorological conditions, a comparison of upwind/downwind concentrations relative to the central Washington, D.C. area where precursor emissions are heavily concentrated, day of the week comparisons, and major differences in ozone levels at neighboring stations. Average monthly curves showing the diurnal behavior of ozone and other pollutants are also presented. The principal tool used in determining air flow within the area is a computer-calculated trajectory based on surface wind data. Trajectories for each day of the study period are given in Appendix E of this report.

Computer plots of the aircraft data were studied in an attempt to identify the Washington urban plume and the impact of local emissions and transport effects on ozone levels. Selected plots describing the three-dimensional ozone field during the buildup of high ozone levels are included in the discussion.

The hydrocarbon measurements made by RTI during the summer program are summarized by site, by day of the week and by time of day. NMHC/NO_x ratios are calculated from NMHC data obtained by RTI using FID instrumentation and NO_x data reported by the local networks. Hydrocarbon species data are presented and used with results obtained by Lonneman in earlier studies to estimate the contribution of vehicular sources to NMHC concentrations.

SUMMARY CONCLUSIONS

The analyses of the foregoing data sets resulted in the following principal findings:

1. The emission density of both hydrocarbons and nitrogen oxides decreases rapidly with distance from the city center. Except along major highways, the emission densities drop by roughly one order of magnitude in about 8 kilometers outward from the center of Washington, and roughly another order of magnitude in an additional 16 kilometers.

2. On all but 10 days during June, July and August of 1976, the oxidant standard was equalled or exceeded at one or more monitors within the study area. No evidence was found for a trend in the number of violations; recent year-to-year variations in the severity of the oxidant problem are attributed to differences in meteorological conditions.

3. Ozone concentrations at all sites almost always behave in the classical way, with low concentrations at night, a minimum near 0600 a.m., and the daily maximum shortly after noon. When the maximum does occur at night, it rarely exceeds the standard. This suggests domination by locally generated ozone.

4. Changes in the rate of ozone formation appears to occur on an areawide scale with concentrations rising and falling in response to meteorological conditions. Thus violations usually occur at many locations within the study area on a high ozone day.

5. High ozone concentrations are typically associated with high temperatures, at least a moderate amount of solar radiation, and a slowly moving or stagnating air mass that has accumulated a variety of pollutants during its recent history.

6. Although ozone is an areawide phenomenon, substantial differences in maximum concentrations occur at nearby locations as a result of very local influences, such as strong sources of nitric oxide. The practice of monitoring ozone near heavily traveled streets and highways severely limits the usefulness of some of the data for meso and larger scale field studies.

7. No significant difference in the time of the ozone maximum was detected between the upwind and downwind edges of Washington. On the average, however, afternoon concentrations downwind were nearly 20 percent higher than concentrations upwind. Because of difficulty in eliminating the impact of localized site interferences, this conclusion should be considered provisional. Also, the main effects of Washington's emissions downstream could well be occurring outside the monitoring network.

8. An average value of 9.7 was found for the NMHC/NO_x ratio, using data from the Fairfax, Bethesda, Suitland, and CAMP sites and NMHC concentrations determined by flame ionization detection. When data from Fairfax (a residential/commercial site approximately 20 kilometers west of Washington, D.C.) was removed, the ratio was 6.7.

9. NMHC concentrations, averaged from six sites over the 0600 to 0900 a.m. period showed Saturday and Sunday concentrations to be 77 and 91 percent, respectively, of weekday concentrations.

10. Application of Lonneman's procedures for estimating the vehicular contribution to ambient NMHC concentrations was impaired by the limited number of hydrocarbon species that were measured by gas chromatographic analysis. The use of his approach with an estimate of total NMHC obtained by flame ionization detection, indicated that, on the average, vehicular emissions accounted for approximately 56, 77, 97, and 92 percent of the total NMHC measured at the Alexandria, CAMP, Fairfax, and Bethesda sites, respectively.

11. Although individual hydrocarbon/acetylene ratios varied widely at the same site, the average ratios, with the notable exceptions of ethylene/ethane and toluene, showed good agreement among sites. Comparison of the average ratios with the values reported by Lonneman from tunnel experiments showed ratios at the four study sites from 2.5 to 8 times higher than tunnel ratios for toluene; roughly 2 times higher for n-butane, isopentane, n-pentane, and isobutane; and slightly lower for propylene. No tunnel ratio for ethylene/ethane was available for comparison. The amounts of 1-butene and cyclopentane found were too small to impact significantly on the total amount of NMHC, and were less than would have been expected from the tunnel experiments. Providing measured levels are valid, these comparisons suggest the presence of major sources of toluene (and of ethylene/ethane) in addition to motor vehicles, plus lesser, more uniformly distributed nonvehicular sources of the other principal hydrocarbon species. The lack of better agreement between the tunnel ratios and the ratios at Bethesda and Fairfax where NMHC concentrations had been estimated to be primarily from motor vehicles (see 10, above) is unexplained.

12. Although significant differences in ozone concentration were encountered in horizontal flight, aircraft sampling at an altitude of about 670 meters (2200 ft) failed to show any major increase in ozone that could be directly related to Washington's emissions. However, flight restrictions prevented a careful search for the Washington plume which may not have been located at flight altitude at the sampling distances employed.

SECTION I

INTRODUCTION

PROJECT OVERVIEW

With the discovery that the oxidant problem is widespread, and not centered primarily in the vicinity of a few major urban areas as originally thought, it has become generally recognized that revised procedures are needed to guide the development of oxidant control plans. This report covers one small part of EPA's continuing effort to collect and analyze observational data which might prove useful in making these revisions. Washington, D.C. and its environs was selected for study partly because of its known oxidant problem, and partly because of the possibility that an influx of summertime visitors during the 1976 Bicentennial Year might result in a clearly definable increase in oxidant levels which could then be associated directly with a measured increase in vehicular travel.

As stated in the Foreword, a review of the problem and an examination of data sources at the start of the project showed the impracticality of attempting to relate changes in vehicle miles traveled directly to changes in oxidant levels.[1] Estimates indicated that the maximum increase in VMT likely to occur between the summers of 1973 and 1976 would not exceed 10 percent. The possibility of detecting the effect of such a small change in VMT on observed oxidant levels was judged to be extremely small in view of the large variations which frequently occur from year to year as a result of differences in meteorological conditions. Furthermore, the available traffic data were inadequate to define areawide changes in VMT for comparison with oxidant levels on a daily basis. As a result, the characterization of the oxidant problem in the area became the principal thrust of the work.

To provide background information on the problem, oxidant levels during the past 4 years are examined briefly in this introduction. Section II describes the data available for the study, and the remainder of the report uses these data to describe the magnitude and geographical extent of the problem and to explore the part played by the transport of ozone and precursors to the high oxidant concentrations observed with the monitoring network.

SHORT TERM TREND

Recent (1973 to 1976) ozone data at five Virginia sites were reviewed for obvious year-to-year changes that might indicate a trend in oxidant levels or the frequency of violations of the standard. Figure 1a, taken from the 1976 Annual Report of the Fairfax County Health Department,[2] presents a year-by-year comparison of the highest 1-hour ozone concentrations observed at four sites during the 1973 to 1976 period. For this 4-year period, the 1-hour maximums were lowest in 1974 and highest in 1975. A more broadly based statistic, and hence a more reliable one for determining trend, is the number of hours above the standard. This number has been plotted in Figure 1b for the 1973 to 1976 period. Again, 1974 appears as the best year, that is, the year with the fewest violations. Also, 1976 has fewer violations than 1975. Because only two of the monitors were operated in 1973, it is not as clear how 1973 violations compare with those in 1975 and 1976, but 1973 appears to have been quite similar to 1975 and 1976.

Figure 1c shows a different type of year-to-year comparison using an Alexandria site. Here, the number of hours at or over the standard has been plotted for each hour of the day. Once again, 1974 is the best year and no regular trend is evident, although the two most recent years experienced nearly twice as many violations as the two earlier years.

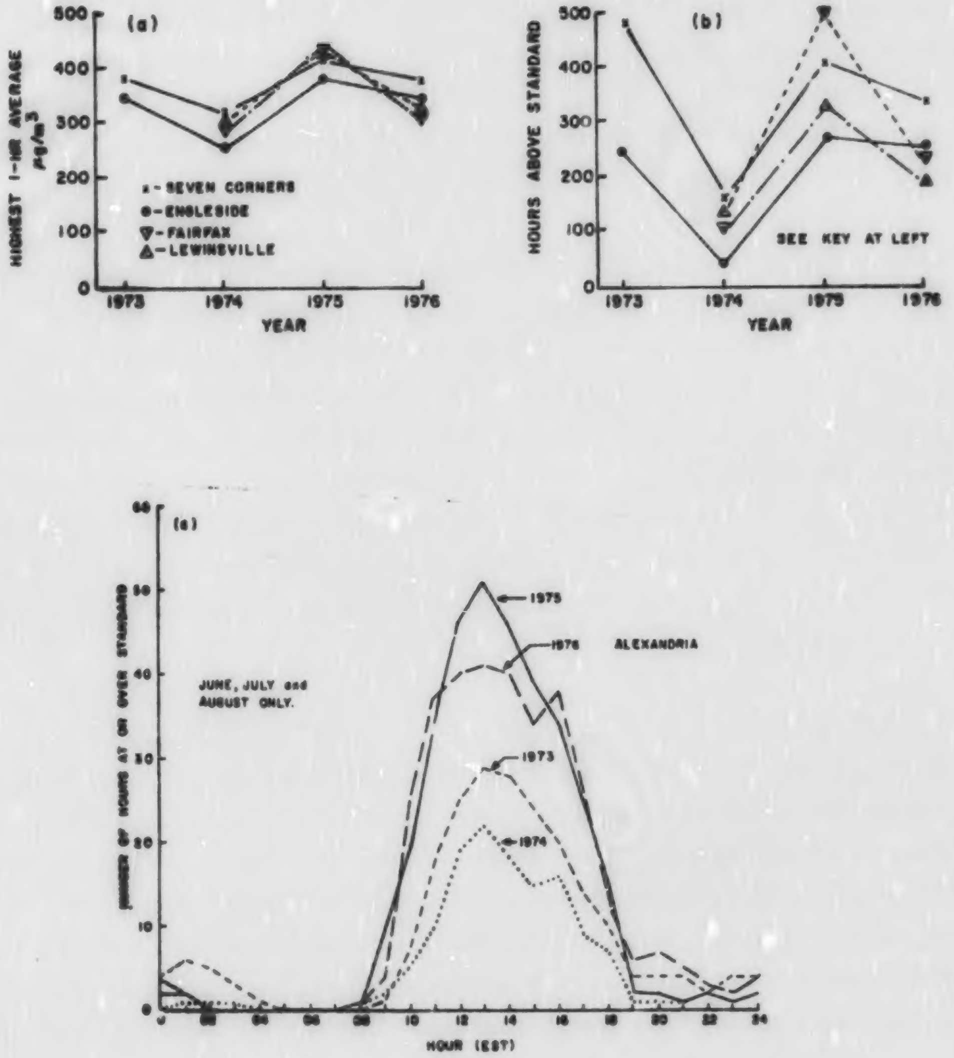


Figure 1. Comparison of high ozone concentration at five Virginia monitoring sites during 1973-1976

A comparison of the severity of the oxidant problem during each of the 4 years can also be made by comparing the number of Air Pollution Alerts. A history of Air Pollution Alerts has been prepared by the Metropolitan Washington Council of Governments and is included as Appendix A of this report. In summary, during the months of June through August, there were five alerts called in 1973, one in 1974, three in 1975, and six in 1976. The total number of alert days in each of the 4 years was: 22 in 1973, 4 in 1974, 14 in 1975, and 20 in 1976.

Taken together, these various measures of the severity of the oxidant problem suggest that the years 1973, 1975, and 1976 were roughly comparable. On the other hand, all indices have indicated that the problem was less severe in 1974 than during the other 3 years. Since there was no known large decrease in 1974 emissions, the explanation for the lower oxidant levels presumably lies in differences in meteorological conditions. It was outside the scope of work of this contract to investigate this possibility in depth, but the important role played by meteorology in the formation and transport of oxidants has been well documented by other investigations.[3-9]

Climatological data from National Airport were examined briefly for relationships between meteorological indices and the severity of the oxidant problem during these 4 years. Table 1 lists indices, calculated for June, July, and August, which indicate that the summer period in 1974 was colder, and had less sunshine, than the corresponding periods of the other 3 years. The small number of Air Pollution Alert days during 1974 suggests that there were also few periods when slowly moving or stagnating high pressure cells dominated Washington's weather that year.

Table 1. TEMPERATURE AND RADIATION INDICES DURING SUMMER MONTHS, 1973-1976

	1973	1974	1975	1976
Average temperature (F)	78.7	76.3	78.6	77.6
Percent possible sunshine	64	58	65	70

SECTION II

THE DATA BASE

The various summaries and analyses presented in this report are based on the following sets of data, some of which were obtained from the regularly operated surface networks and ongoing activities, and some from special measurement programs:

- Emission inventory data
- Routine surface network data
- Meteorological data
- Traffic count data
- Special THC, CH_4, NMHC, and CO observations
- Detailed HC composition data
- Aircraft observations

Brief descriptions of these seven data sets follow.

EMISSION INVENTORY DATA

HC and NO_x emission inventory data were provided by the Metropolitan Washington Council of Governments for the base year 1973. No projections to 1976 were available, but is unlikely that many major changes in the emission pattern have occurred during that 3-year period. Details of the procedures used to develop the inventory are given in a report available from COG.[10] Area source emissions for HC and NO_x were provided GCA for each of the 145 Policy Analysis Districts in the Washington metropolitan region, and a point source emission inventory was provided for the major NO_x sources.

ROUTINE SURFACE NETWORK DATA

The surface networks operated by the local agencies to monitor ozone and other gaseous pollutants of interest to this program comprise 18 stations. In addition, measurements were being made during the study period at and in the vicinity of Dulles International Airport by the Federal Aviation Admimistration as part of its program to monitor operations of the Concorde airplane. The locations of these 19 sites are shown in Figure 2, and a check list of the pollutants measured at each station is given in Table 2. As might be expected, there was a wide range in the degree of completeness of the data among the various sites.

METEOROLOGICAL DATA

The surface meteorological data used in the analyses consisted of local climatological data from the National Weather Service stations at National and Dulles International Airports, wind speed and direction from eight local agency sites in Virginia and Maryland, and solar radiation data from the Alexandria Health Department site. The locations of these meteorological stations are shown in Figure 3. In addition to the two regular upper air soundings which are made at Sterling, Virginia, one additional sounding per day (at approximately 1300 EST) was made during July and August in support of this program. Mixing heights calculated by EPA from the soundings made during this 2-month period are listed in Appendix B.

TRAFFIC COUNT DATA

Daily traffic volume data were supplied by the Washington Department of Transportation, through COG, for the following three sites: 1) Memorial Bridge, 2) Anacostia Freeway at Howard, and 3) South Capitol Street Bridge.

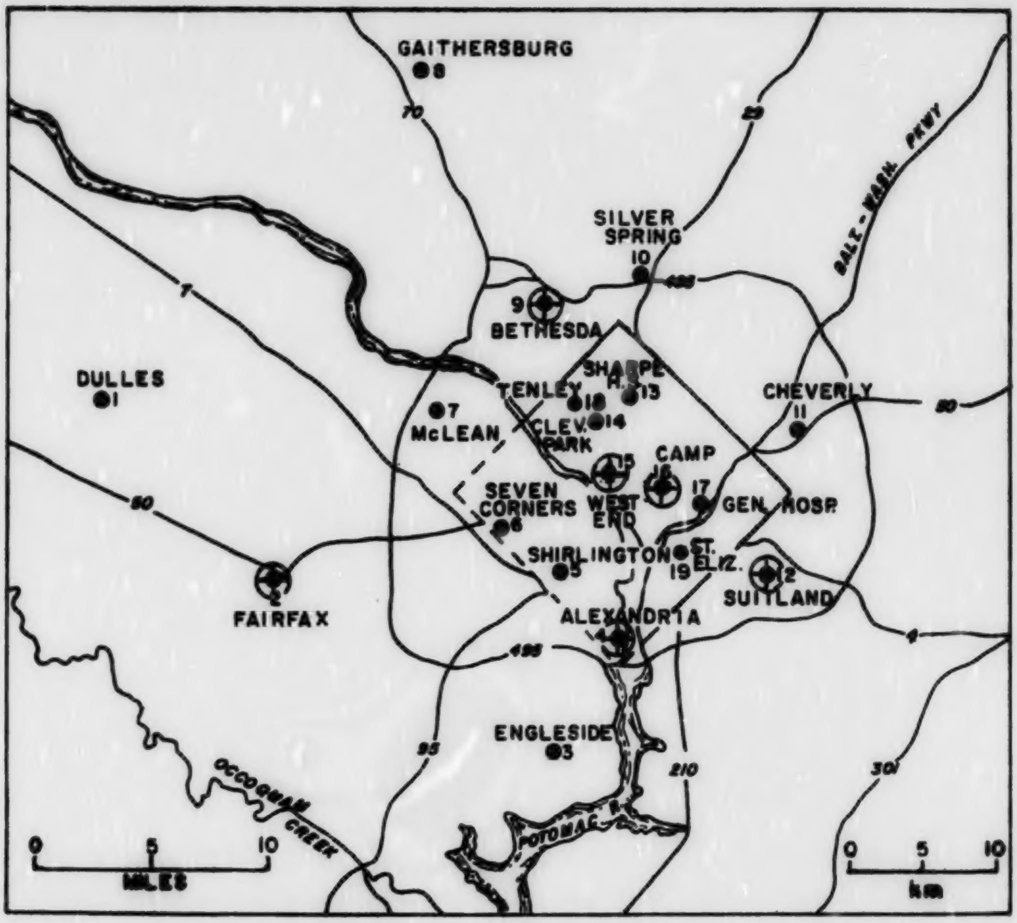

GAITHERSBURG
8
70
29
BALT.-WASH. PKWY
SILVER SPRING
10
495
7
9
BETHESDA
DULLES
1
SHARPE H.
13
TENLEY
18
CHEVERLY
11
50
7
McLEAN
CLEV. PARK
14
15
CAMP
16
17
SEVEN CORNERS
WEST END
GEN. HOSP.
6
50
SHIRLINGTON
ST. ELIZ.
19
5
12
2
SUITLAND
FAIRFAX
ALEXANDRIA
4
495
4
ENGLESIDE
3
95
210
301
OCCOQUAN CREEK
POTOMAC R.
0
5
10
MILES
0
5
10
km

Figure 2. Distribution of monitors throughout Washington metropolitan area. Ozone is measured at Sites 1 through 17. Special HC sites are indicated by the symbol ⊕

Table 2. SUMMARY OF AIR QUALITY AND METEOROLOGICAL DATA AVAILABLE FOR ANALYSIS (EXCLUDING AIRCRAFT MEASUREMENTS)

Sampling site		Pollutant measured							Meteorological data		
Map no.	Designation[a] and location	Special program[b]	O_3	NO_2	NO	THC	CH_4	CO	Wind speed and direction	Solar radiation	Upper air sounding
1	Dulles International Airport, Sterling, Virginia		X	X	X	X	X	X	X		X
2	Massey Bldg., Fairfax, Virginia	X	X	X	X			X			
3	Engleside, Alexandria, Virginia		X	X	X			X			
4	Health Dept., Alexandria, Virginia	X	X	X				X		X	
5	Shirlington, Arlington, Virginia		X					X			
6	Seven Corners, Falls Church, Virginia		X	X	X	X	X	X	X		
7	Lewinsville, McLean, Virginia		X	X	X	X	X	X	X		
8	Gaithersburg Lab., Gaithersburg, Maryland		X					X			
9	Airmon No. 6, Bethesda, Maryland	X	X	X	X			X			
10	Airmon No. 5, Silver Spring, Maryland		X	X	X			X			
11	Airmon No. 4, Cheverly, Maryland		X	X	X			X			
12	Airmon No. 3, Suitland, Maryland	X	X	X	X			X			
13	Sharpe Health School, Washington, D.C.		X					X			
14	Cleveland Park Library, Washington, D.C.		X	X							
15	West End Library, Washington, D.C.	X	X	X				X			
16	CAMP Station, Washington, D.C.	X	X	X	X			X			
17	D.C. General Hospital, Washington, D.C.		X	X	X			X			
18	Tenley-Friendship Library, Washington, D.C.							X			
19	St. Elizabeth's Hospital, Washington, D.C.			X	X			X			
20	National Airport, Washington, D.C.								X		
21	Westgate, Alexandria, Virginia								X		
22	Occoquan Hill, Occoquan, Virginia								X		
23	Ravensworth, Springfield, Virginia								X		
24	Benchmark, Fairfax, Virginia								X		
25	Great Falls, Virginia								X		
26	County Office Bldg., Rockville, Maryland								X		

[a] Site name used throughout this report is designated by an underline.

[b] Special HC, detailed HC and CO sampling program (RTI).

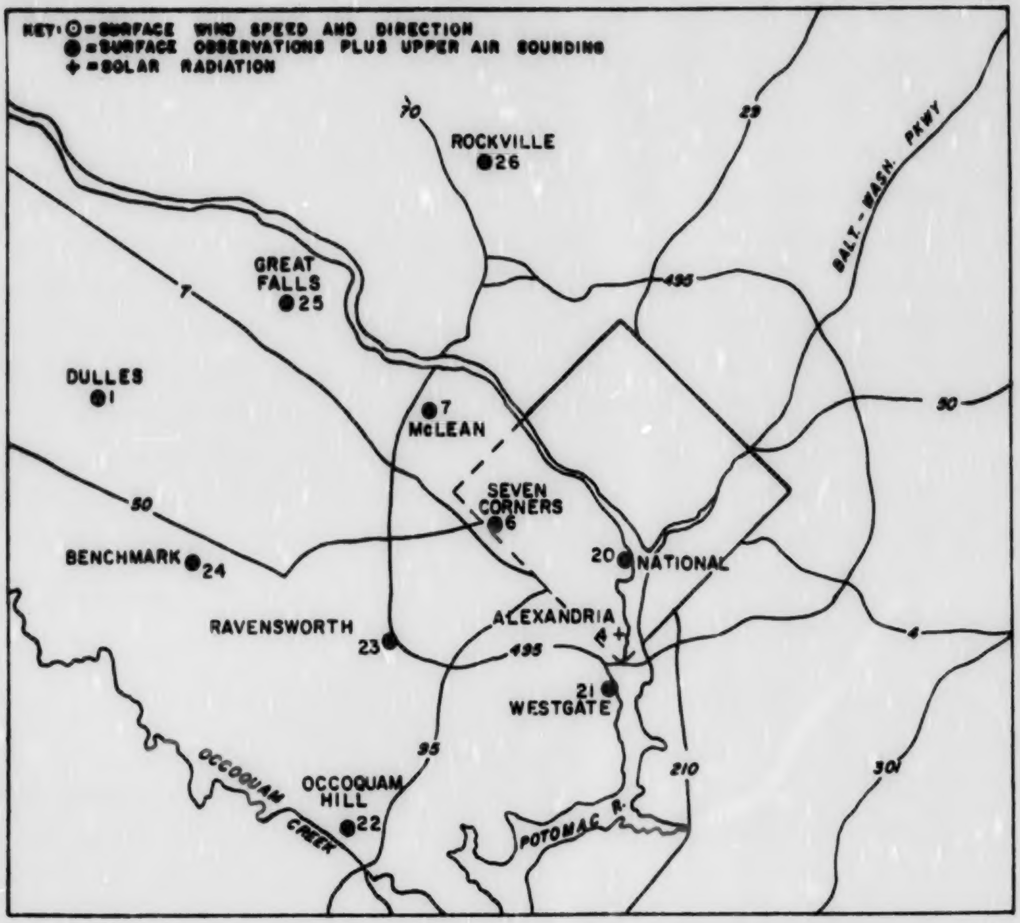

KEY: ⊕ = SURFACE WIND SPEED AND DIRECTION
● = SURFACE OBSERVATIONS PLUS UPPER AIR SOUNDING
+ = SOLAR RADIATION
ROCKVILLE
26
GREAT FALLS
25
DULLES
1
7
McLEAN
SEVEN CORNERS
6
BENCHMARK
24
20
NATIONAL
ALEXANDRIA
4
RAVENSWORTH
23
21
WESTGATE
OCCOQUAM HILL
22
OCCOQUAM CREEK
POTOMAC R.
BALT.-WASH. PKWY
70
29
495
7
50
50
4
95
210
301

Figure 3. Meteorological network. Locations of wind monitoring stations are shown by ●'s; solar radiation monitor by a +, and surface and upper air station by a ⊕

Traffic counts were provided each day for the 0900 to 1600 EDT period as well as for the 24-hour period. These data were incorporated into the weekly reports which summarized tourist activity and ozone concentrations on a current basis.

SPECIAL THC, CH$_4$, NMHC, AND CO OBSERVATIONS

Ambient concentrations of total hydrocarbons (THC), methane (CH$_4$), non-methane hydrocarbons (NMHC) and carbon monoxide (CO) were measured at six sites by Research Triangle Institute as part of the overall data collection program. THC, CH$_4$ and CO concentrations were measured in grab samples using a Beckman 6800 Air Quality Chromatograph. Except for occasional periods when technical problems were experienced, integrated concentrations over 3-hourly periods from 0600 until 1800 EDT were obtained on a daily basis from July 3rd through September 1st. The sampling and analysis protocol for this program, and the raw data, are described in RTI's Final Data Report.[11] The six sites (Fairfax, Bethesda, Suitland, Alexandria, West End and CAMP) are distributed both within and around the District of Columbia, as shown in Figure 2.

DETAILED HC COMPOSITION DATA

Detailed hydrocarbon analyses of 10 percent of the grab samples described above were analyzed by RTI using a modified Perkin-Elmer Model 900 gas chromatograph coupled to a Hewlett-Packard 2100A computer programmed for peak area analysis. Each sample was analyzed routinely for the 11 hydrocarbons listed below:

1) ethane and ethylene
2) acetylene
3) propane
4) propylene
5) isobutane
6) n-butane
7) 1-butene
8) isopentane
9) cyclopentane
10) n-pentane
11) toluene

Procedural details and the raw data are also tabulated in RTI's Final Data Report.[11]

AIRCRAFT OBSERVATIONS

Concentrations of O_3, NO, NO_x, SO_2, and condensation nuclei were measured by the EPA Air Quality Branch of the Environmental Monitoring and Support Laboratory — Las Vegas during 16 flights beginning on August 17, 1976 and ending on August 27, 1976. The instrumented B-26 aircraft used during the study was based at the Baltimore International Airport. The sampling aircraft was restricted to altitudes greater than 610 meters (2000 feet) while flying in the vicinity of the Washington Tower Control Area (TCA). Flight patterns began with circles flown around the perimeter of the Washington TCA (diameter about 60 kilometers, or 37 miles) at an altitude of 610 to 670 meters (2000 to 2200 feet). Patterns evolved into longer flights as the stagnation period which occurred during the sampling period developed. Typically, one or more spiral soundings were made at preselected locations during each flight.

SECTION III

DISTRIBUTION OF PRECURSOR EMISSIONS

Figure 4 identifies by number the 145 planning districts into which the Washington metropolitan region is divided. The Metropolitan Washington Council of Governments supplied the area of each district and an annual estimate of its total HC and NO_x emissions for the 6 to 9 a.m. period based on the conversion factors given in Table 3. This information was used to calculate emission densities from which the maps shown in Figures 5 through 12 were prepared. A set of four emission density maps is presented for each pollutant. Two of these show the whole AQCR, and two show the 16-kilometer (10-mile) square containing the District of Columbia in a larger scale. In each case, one map gives the calculated emission density by planning district, and the second map depicts, in a less detailed fashion, the geographical differences in emissions by differences in shading.

In the case of hydrocarbons, emissions are considered as total emissions from all sources, but in the case of nitrogen oxides, the very significant emissions from major point sources have not been included. These point source emissions have been roughly consolidated in Figure 13, which shows the approximate location and magnitude of grouped sources. The three major power plants, Chalk Point, Dickerson, and Possum Point, located in the outskirts of the region, contribute large quantities of NO_x to the regional inventory, as shown by Figure 13. In addition to the point source emissions included in the totals shown in Figure 13, approximately 1000 kilograms per 3 hours are emitted within the 16 kilometer square, largely along the Potomac and Anacostia Rivers.

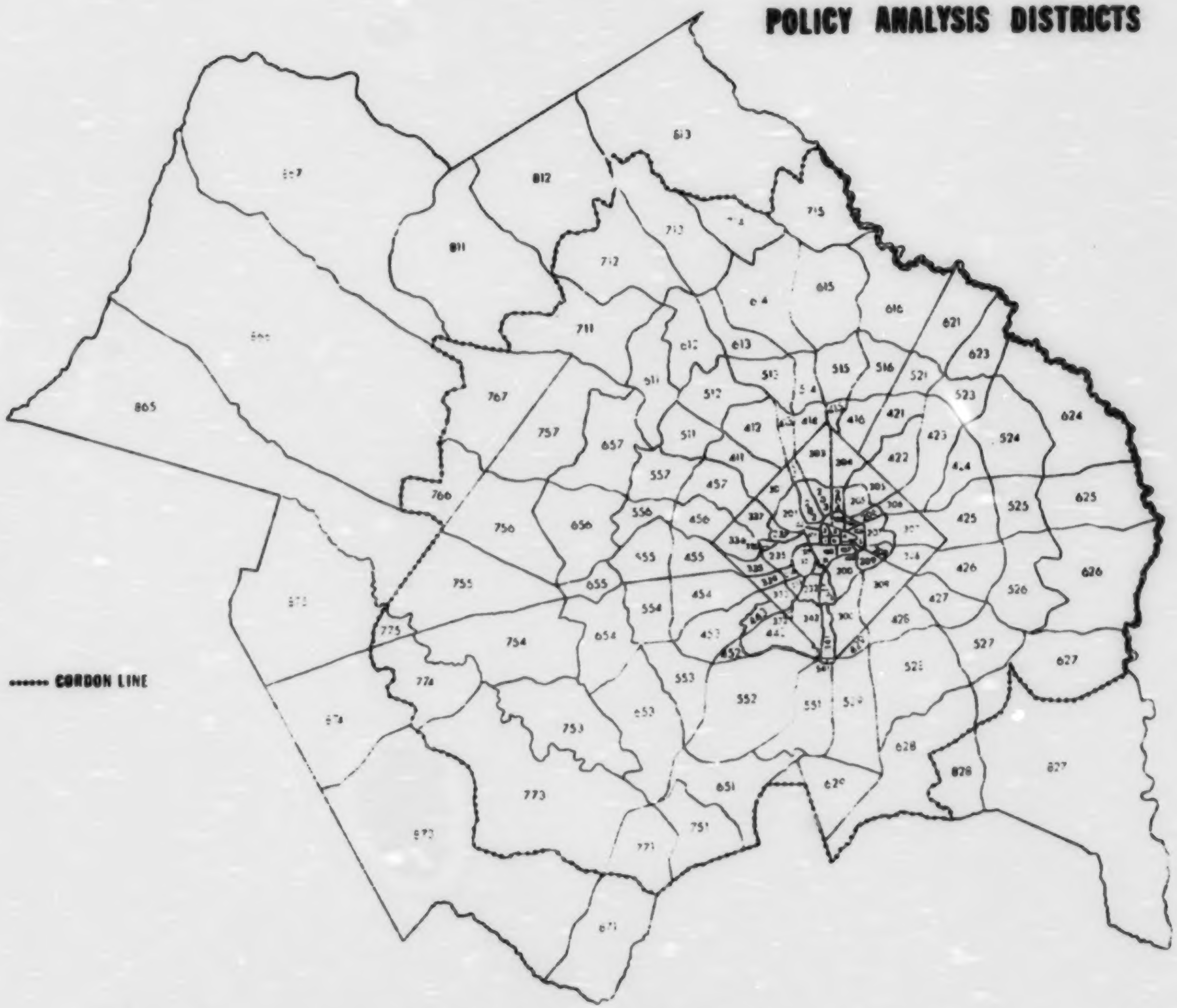

POLICY ANALYSIS DISTRICTS
CORDON LINE
813
812
811
865
715
712
711
767
757
766
756
755
754
753
773
751
615
616
621
623
624
625
626
627
628
827
828
613
515
516
521
523
524
525
526
527
511
512
557
556
555
554
553
552
551
657
656
655
654
653
651
411
412
416
421
422
423
425
426
427
457
456
455
454
303
304
337
200

Figure 4. Planning districts for the Washington metropolitan region

Table 3. PEAK PERIOD CONVERSION FACTORS
(Daily to 6-9 a.m.)

Source	Factor, %
Auto	
VMT	18.3
Trips	14.5
Trucks	16.5
Aircraft	13.0
Petroleum	
Storage	12.5
Handling	17.0
Service stations	17.0
Solvents	12.5
Dry cleaning	12.5
All others	12.5

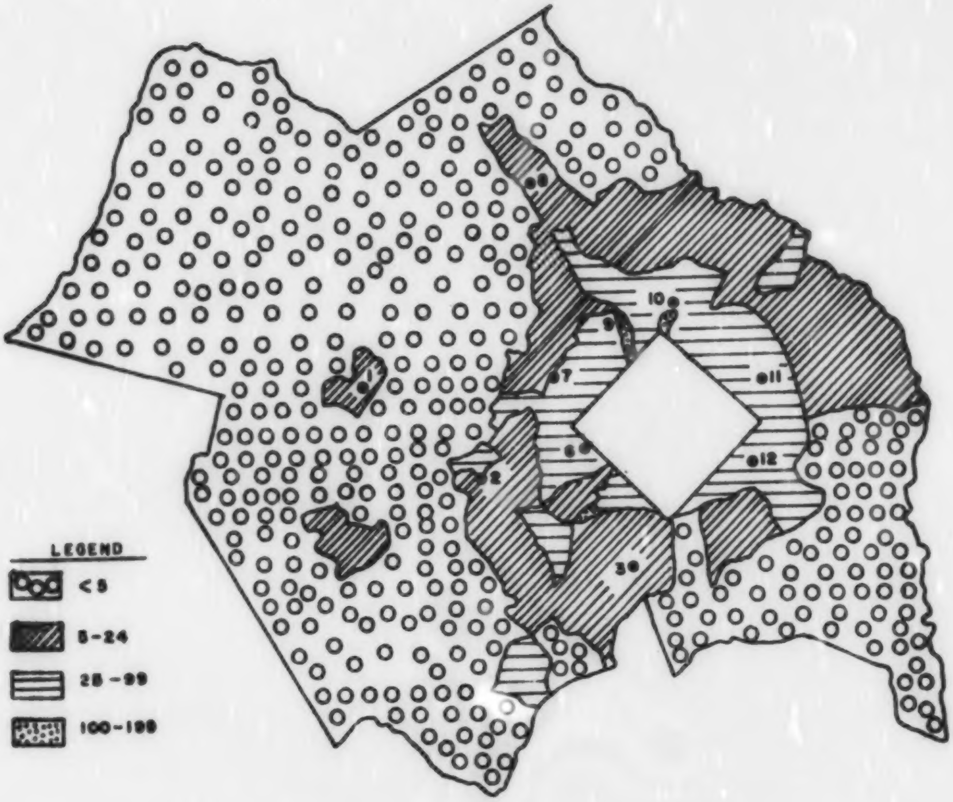

LEGEND
< 5
5-24
25-99
100-199
1
2
3
6
7
8
9
10
11
12

Figure 5. Emission density map of total hydrocarbons for the National Capitol AQCR. Units are kg/km^2/6 to 9 a.m. Filled circles show locations of ozone monitors (see Figure 6 for central area)

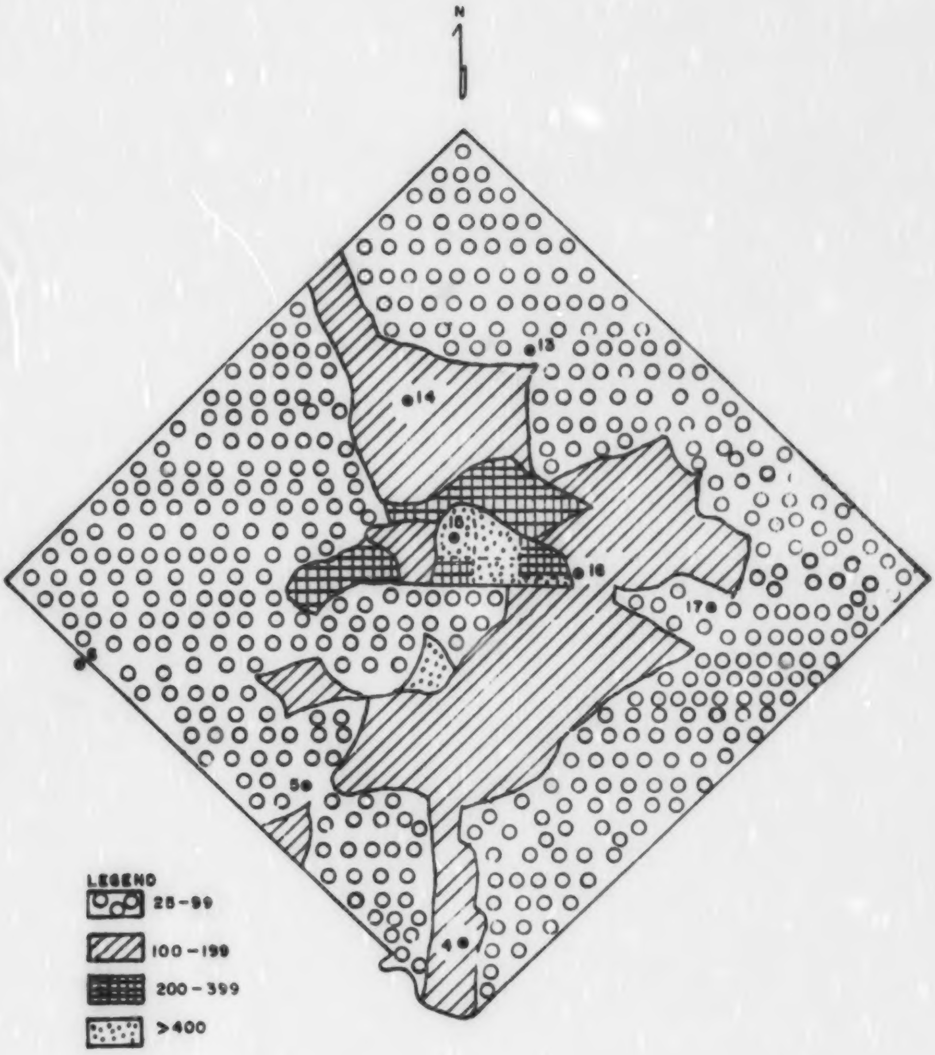

N
13
14
15
16
17
5
4
LEGEND
25-99
100-199
200-399
>400

Figure 6. Emission density map of total hydrocarbons for central metropolitan Washington area. Units are kg/km^2/6 to 9 a.m. Filled circles show locations of ozone monitors

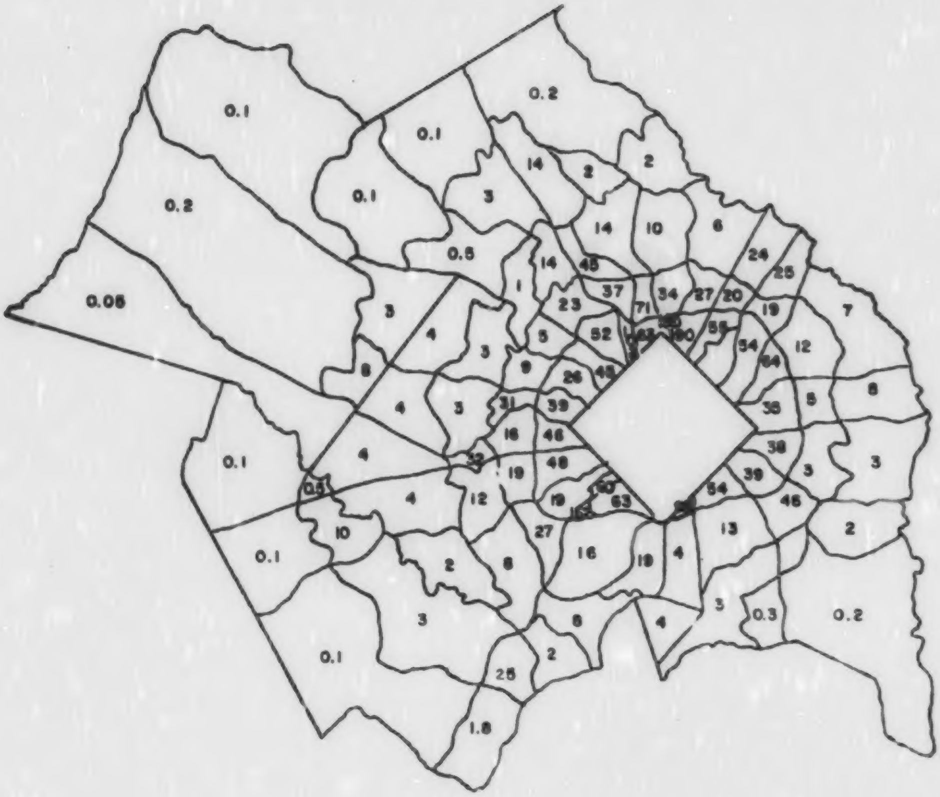


Figure 7. Emission density of total hydrocarbons by planning district within the National Capitol AQCR. Units are kg/km^2/6 to 9 a.m. (see Figure 8 for central area)

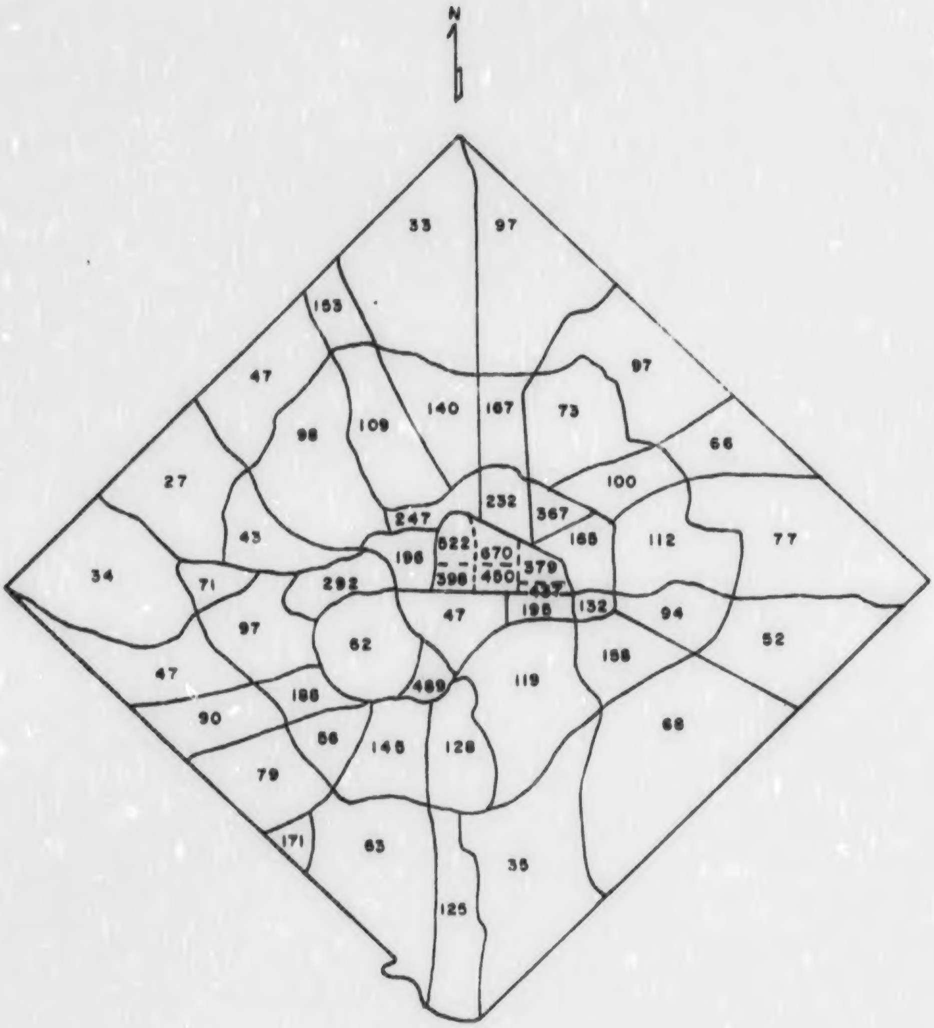

N
33
97
153
47
97
140
167
73
109
98
66
27
100
232
367
247
43
522
670
168
112
77
34
196
379
71
292
398
450
437
47
196
132
94
97
62
52
158
47
468
119
186
90
68
56
145
128
79
171
63
35
125

Figure 8. Emission density of total hydrocarbons by planning district within central metropolitan Washington area. Units are kg/km^2/6 to 9 a.m.

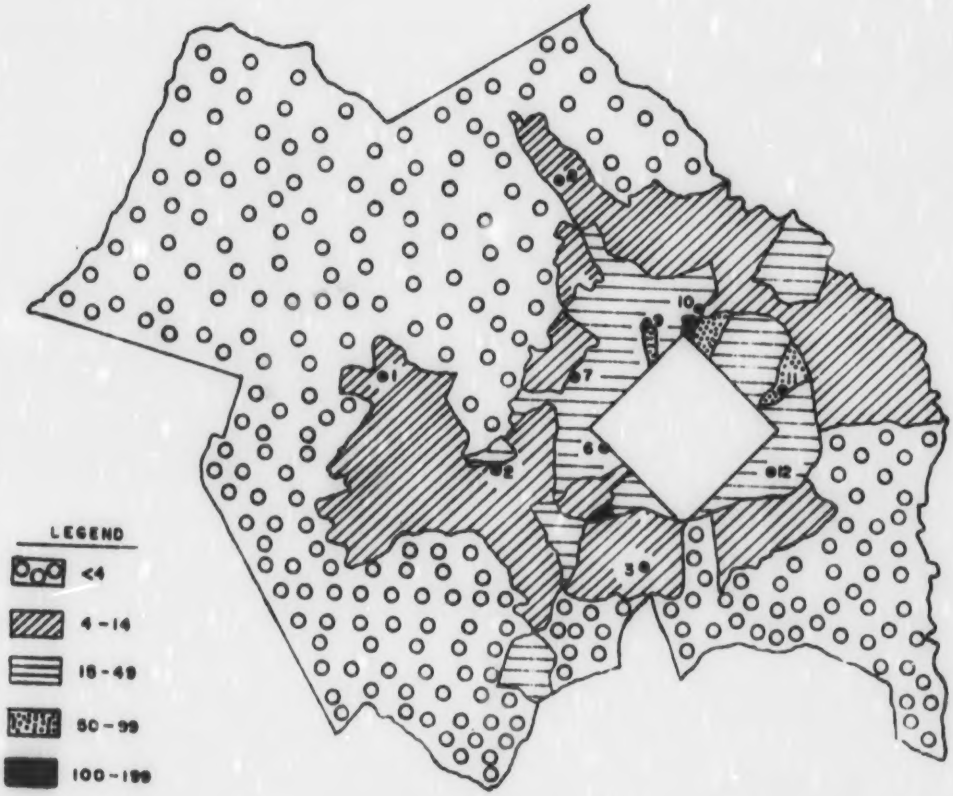

LEGEND
<4
4-14
15-49
50-99
100-199
1
2
3
6
7
8
9
10
11
12

Figure 9. Emission density map of nitrogen oxides for the National Capitol AQCR. Units are kg/km^2/6 to 9 a.m. Filled circles show locations of ozone monitors (see Figure 10 for central area)

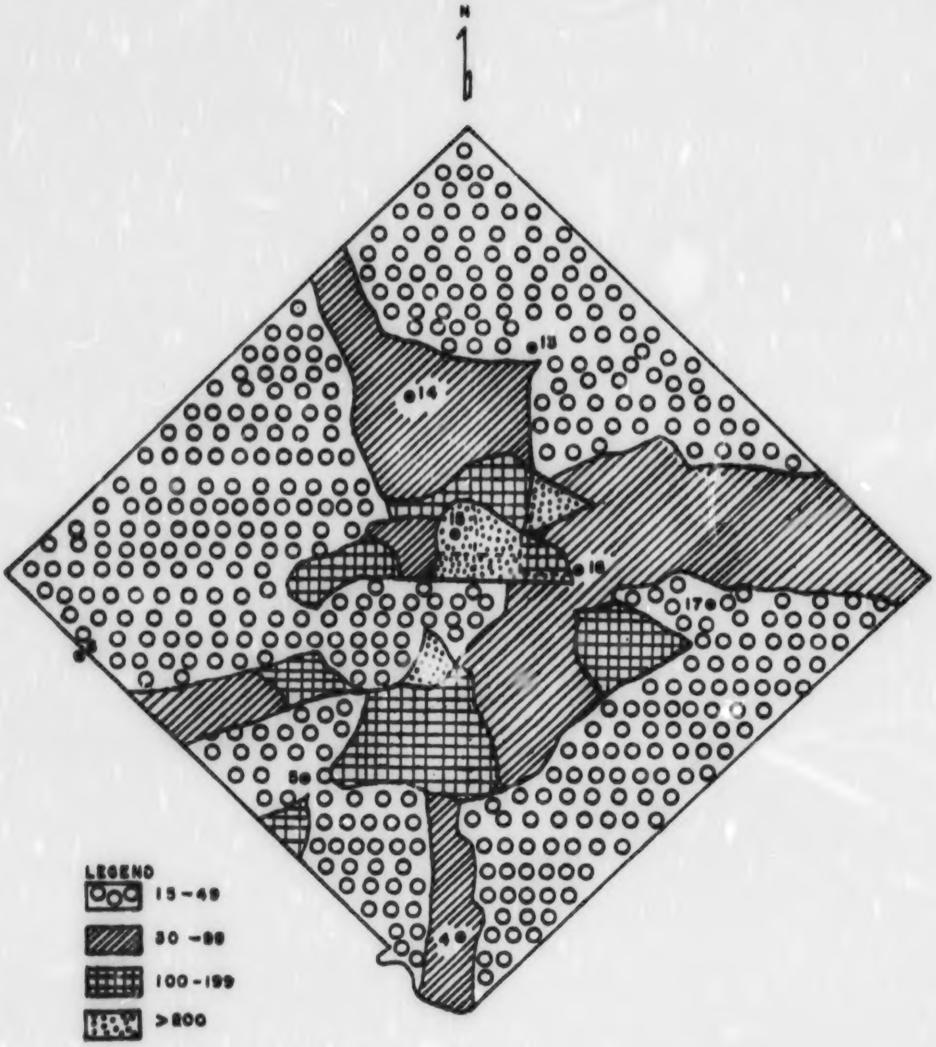

N
13
14
16
17
5
4
LEGEND
15-49
50-99
100-199
>200

Figure 10. Emission density map of nitrogen oxides for central metropolitan Washington area (area sources only). Units are kg/km^2/6 to 9 a.m. Filled circles show locations of ozone monitors

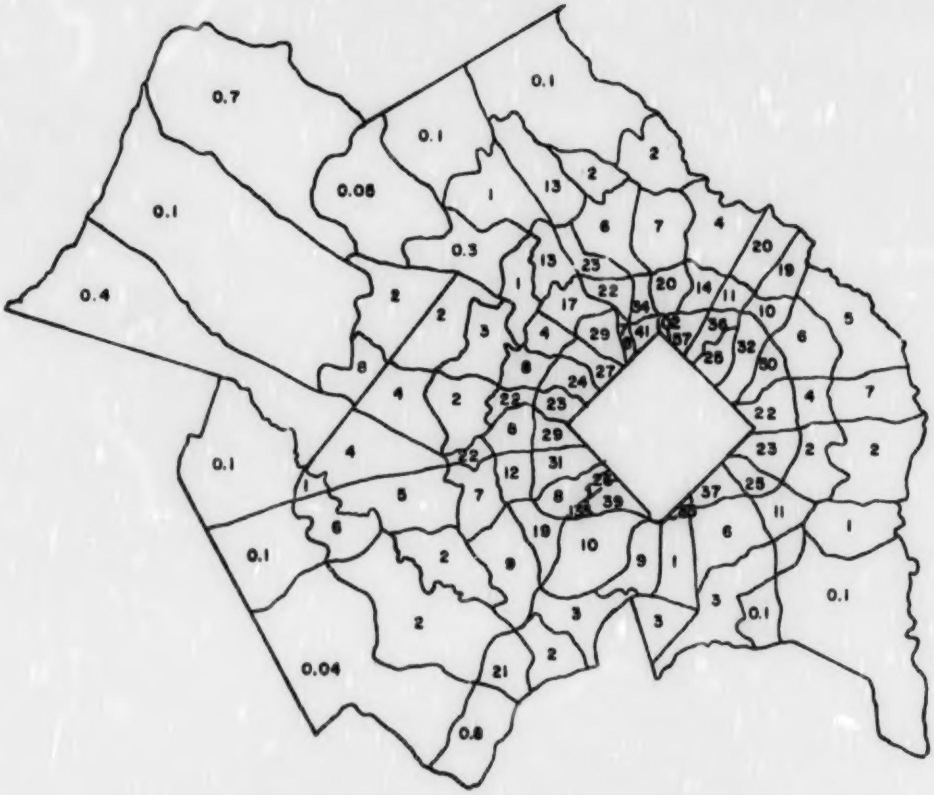

0.7
0.1
0.1
0.06
1
13
2
2
0.4
0.3
6
7
4
20
19
13
25
1
2
22
20
14
11
2
3
17
34
10
5
4
29
41
102
36
157
32
6
8
26
8
24
27
30
4
7
4
2
22
23
22
8
2
29
23
2
0.1
4
22
12
31
25
26
1
5
7
8
39
37
155
11
6
19
10
6
1
0.1
2
9
9
1
2
3
3
3
0.1
0.1
2
21
0.04
0.8

Figure 11. Emission density of nitrogen oxides by planning district within the National Capitol AQCR (area sources only). Units are kg/km^2/6 to 9 a.m. (see Figure 12 for central area)

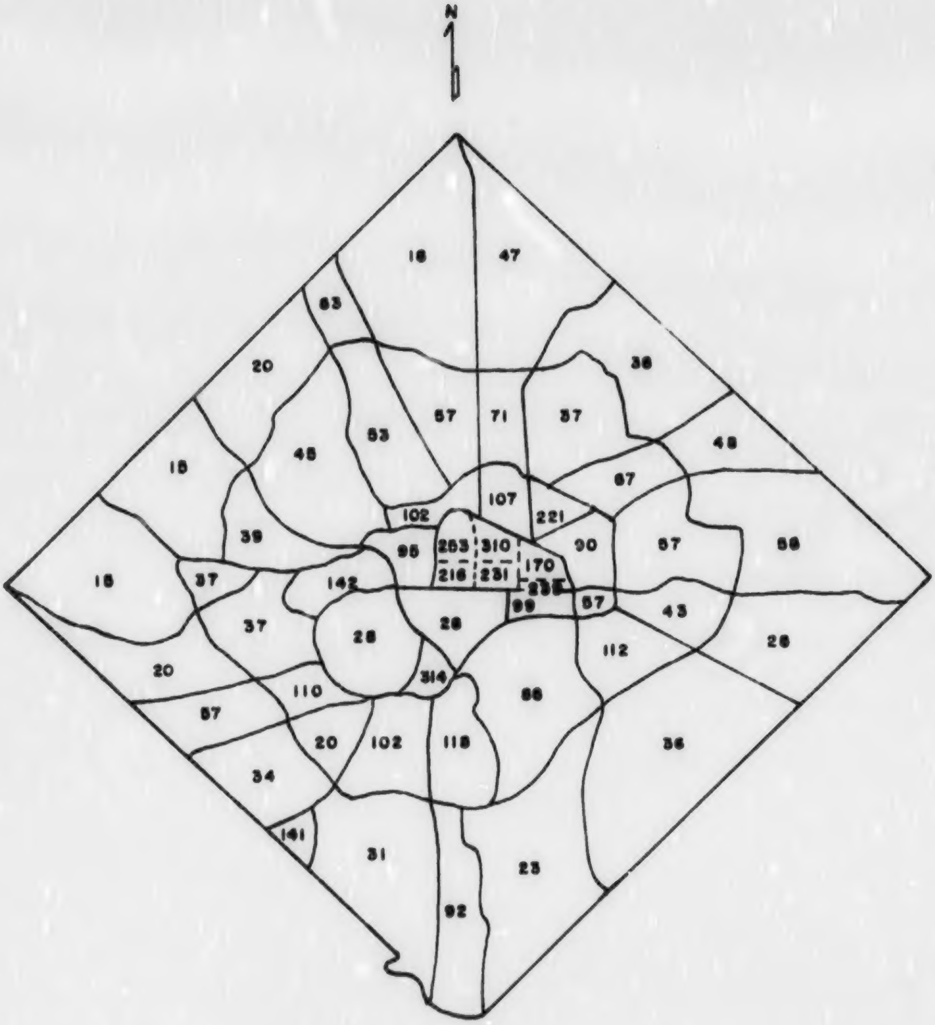

N
16
47
63
20
38
57
71
37
15
45
53
48
67
107
102
221
39
95
263
310
90
57
58
15
37
142
216
231
170
235
99
57
43
37
28
26
112
26
20
314
110
86
57
20
102
118
36
34
141
31
23
92

Figure 12. Emission density of nitrogen oxides by planning district within central metropolitan Washington area (area sources only). Units are kg/km^2/6 to 9 a.m.

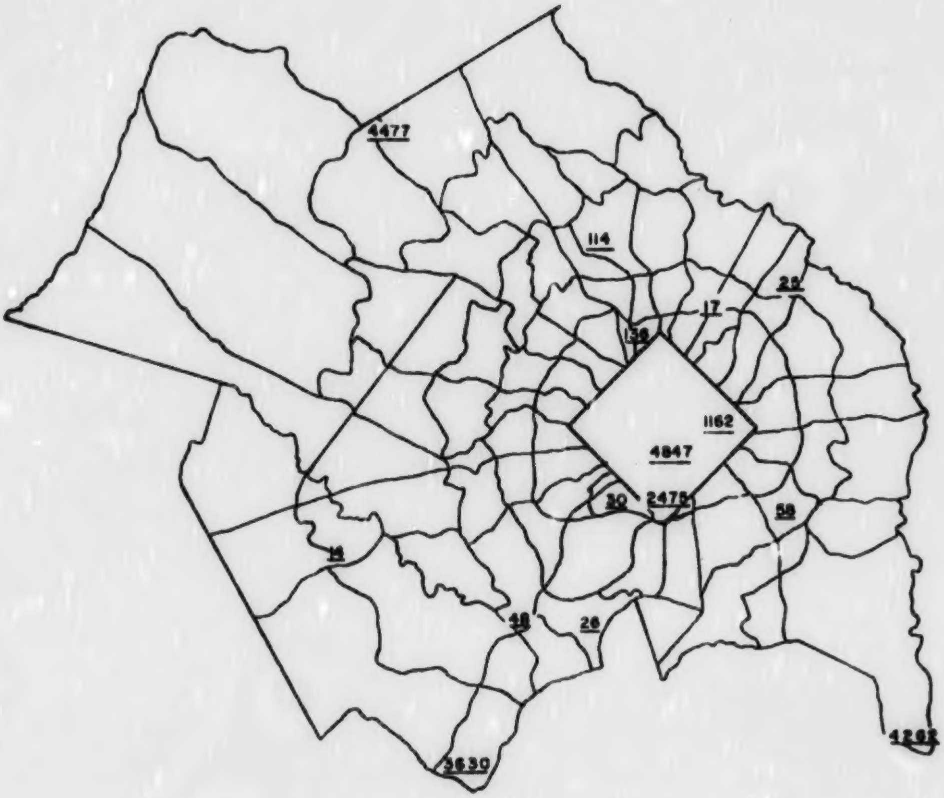

4477
114
29
17
136
1162
4847
30
2475
58
14
48
26
3630
4292

Figure 13. Emission rates of nitrogen oxides from grouped point sources. Units are kg/ 3 hours

As would be expected, the emission density of both hydrocarbons and nitrogen oxides decreases rapidly with distance from the city center. For example, except along major highways, the emission densities drop by roughly one order of magnitude in about 8 kilometers (5 miles) outward from the center of Washington, and by roughly another order of magnitude in an additional 16 kilometers.

The placement of the 17 ozone monitors with respect to area-source HC and NO_x emissions can be seen in Figures 5, 6, 9, and 10.

A listing of the area and point source emissions within the AQCR, as provided by COG, is given in Appendix C.

SECTION IV

SUMMARY AND INTERPRETATION OF DATA FROM LOCAL NETWORKS

SUMMARY OF OZONE DATA

General

In preparing the summary tables and figures of ozone concentrations presented in this section, emphasis was placed on maximum hourly concentrations and the frequency of violations of the standard. Many of these tables were prepared by hand, which made possible a broadening of the data base by including certain subjectively selected days with partial data. For example, on days with partial data, the highest observed concentration was considered as the maximum if its inclusion appeared to add useful information with regard to the frequency of occurrence of high concentrations. When tabulated, such values are prefixed with a ≥ sign if they were reported next to a period with missing data. In other cases, the data base was expanded by including hours for which concentrations were estimated to be above the standard by modest interpolation or extrapolation. Because of the procedures which were employed in preparing the data summaries, the tables which follow are more appropriate for general descriptive purposes than for rigorous statistical comparisons. During the study, questions arose with regard to some of the Washington, D.C. Agency data for Stations 13, 14, 15, and 17 which had been provided on encoding sheets early in the program. Since these questions centered principally on the hour of entry of the observations and were never fully resolved, summaries in this report which are based on time of day do not include these four stations.

Table 4 lists the maximum 1-hour ozone concentrations measured each day during the 3-month period by station. The two locations in the vicinity of Dulles International Airport where measurements were made by the FAA have been designated 1A and 1B in Table 4. The so-called neighborhood site, 1A, is located at Sterling Park approximately 3-1/2 miles to the north-northeast of the main airport ramp, and Site 1B is located at the south edge of the main ramp, where it is presumably subject to NO scavenging because of its proximity to aircraft exhaust. It is of interest to note that in all but 5 of the 66 days with observations at both locations during this period, the ozone concentration was less at Station 1B than at Station 1A, with an average difference of about 13 percent.

Perhaps the most prominent feature of Table 4, and one which is consistent with general experience, is a tendency for uniform ozone concentrations to occur within the 30-mile by 30-mile study area. For example, June was characterized by concentrations below or near the standard throughout the network during the first 4 days of the month. This period with relatively low concentrations was followed by a period of about 8 days when the standard was substantially exceeded at most sites. These 8 days experienced high temperatures and low resultant wind speeds. Then, with the exception of June 15th, concentrations again were low until the 26th, when maximum concentrations exceeded the standard at 13 of the 17 sites with observations. Measurable precipitation occurred on six of these days having below average concentration, and steady southerly winds prevailed. Widespread high concentrations continued from the 26th through the 29th, a period with generally fair weather, midday temperatures in the upper 80's, and more variable winds. These areawide fluctuations are perhaps more easily seen in Table 5 which gives the number of sites with the maximum concentration equal to or greater than the standard (160 $\mu g/m^3$ or 0.08 ppm). An overall impression gained from Tables 4 and 5 is that the oxidant problem is an areawide phenomenon with concentrations fluctuating in response to changes in the meteorological conditions of the prevailing air mass. On the other hand, examination of Table 4 shows that extreme differences in maximum concentration are sometimes recorded

Table 4. MAXIMUM DAILY OZONE CONCENTRATIONS, $\mu g/m^3$ – JUNE 1976

Date	Day of week	Station identification																	
		Virginia								Maryland					Washington, D.C.				
		DULLES		FAIR	ENG	ALEX	SHIR	SCOR	McL	GAIT	BETH	SSPR	CHEV	SUIT	MSHS	CLEV	WEL	CAMP	DCG
		1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Tues.	–	86	113	103	160*	130	191*	118	120	160*	100	100	120	10	–	110	120	–
2	Wed.	–	38	54	54	60	44	93	54	60	40	40	200*	40	10	–	180*	60	–
3	Thurs.	–	96	127	74	140	70	162*	123	180*	140	80	80	80	20	–	50	90	–
4	Fri.	–	84	162*	78	140	60	172*	142	240*	140	120	80	100	70	–	180*	110	–
5	Sat.	–	90	221*	167*	270*	120	265*	201*	200*	200*	200*	180*	190*	60	–	100	130	–
6	Sun.	–	84	181*	176*	180*	164*	196*	157	180*	140	140	160*	140	70	–	130	150	–
7	Mon.	–	70	191*	201*	210*	190*	206*	176*	220*	180*	200*	220*	180*	90	–	140	170*	–
8	Tues.	–	80	201*	265*	280*	230*	260*	196*	200*	≥180*	≥200*	≥180*	≥200*	100	–	130	190*	–
9	Wed.	–	200*	230*	≥348*	360*	220*	255*	211*	160*	220*	380*	380*	360*	170*	–	280*	210*	–
10	Thurs.	–	200*	284*	260*	280*	200*	314*	230*	220*	340*	100	≥260*	240*	380*	–	200*	190*	–
11	Fri.	–	200*	–	265*	250*	330*	274*	221*	≥240*	≥180*	240*	260*	≥260*	310*	–	210*	210*	–
12	Sat.	–	150	–	240*	290*	324*	250*	201*	240*	–	200*	240*	200*	250*	90	170*	200*	–
13	Sun.	–	80	–	74	120	110	118	88	140	–	80	80	100	120	40	220*	95	–
14	Mon.	–	110	–	74	110	50	113	69	100	–	60	60	80	150	160*	120	64	–
15	Tues.	–	144	–	167*	220*	≥110	225*	176*	200*	≥180*	–	100	–	276*	130	80	140	–
16	Wed.	–	54	–	74	90	40	98	54	100	80	–	–	60	110	110	80	50	–
17	Thurs.	–	102	–	34	130	44	122	83	120	180*	60	100	100	180*	90	130	80	50
18	Fri.	–	116	–	49	≥140	50	132	88	120	140	40	60	120	170*	150	120	90	70
19	Sat.	–	80	–	44	150	60	122	88	140	120	40	40	80	150	100	180*	90	90
20	Sun.	–	–	–	49	130	50	122	78	120	100	40	60	–	150	90	160*	90	90
21	Mon.	–	50	–	25	70	36	54	34	80	–	–	–	–	70	60	60	40	50
22	Tues.	–	98	–	34	100	50	113	93	120	–	–	–	–	130	40	110	74	–
23	Wed.	144	100	–	64	130	90	142	118	140	160*	–	–	–	200*	30	50	90	–
24	Thurs.	106	82	–	69	110	76	137	93	80	140	60	60	–	190*	10	40	70	–
25	Fri.	122	102	127	103	120	100	123	98	100	100	80	160*	–	140	20	70	90	–
26	Sat.	180*	162*	196*	245*	240*	130	206*	142	140	160*	180*	200*	≥180*	200*	90	170*	170*	–
27	Sun.	206*	168*	230*	245*	290*	190*	245*	176*	200*	–	–	–	–	310*	80	150	200*	–
28	Mon.	226*	186*	265*	289*	390*	≥220*	343*	191*	200*	280*	200*	220*	320*	380*	90	140	270*	–
29	Tues.	160*	126	196*	167*	270*	200*	260*	–	80	–	160*	260*	220*	620*	110	330*	180*	–
30	Wed.	144	106	137	108	60	124	152	–	40	140	100	100	120	390*	90	140	90	–

Notes: 1A = Sterling Park; 1B = South Ramp
* indicates concentration ≥ standard

Table 4 (continued). MAXIMUM DAILY OZONE CONCENTRATIONS, $\mu g/m^3$ – JULY 1976

Date	Day of week	Station identification																	
		Virginia								Maryland					Washington, D.C.				
		DULLES		FAIR	ENG	ALEX	SHIR	SCOR	McL	GAIT	BETH	SSPR	CHEV	SUIT	MSHS	CLEV	WEL	CAMP	DCG
		1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Thurs.	106	104	118	122	130	104	132	–	–	–	180*	160*	140	400*	90	30	–	120
2	Fri.	138	124	167*	142	130	120	137	132	120	–	140	160*	160*	220*	150	24	–	120
3	Sat.	166*	146	196*	186*	260*	160*	206*	191*	80	–	180*	200*	220*	190*	130	12	–	170*
4	Sun.	128	126	176*	181*	210*	140	181*	157	60	–	160*	160*	160*	200*	190*	12	–	170*
5	Mon.	170*	164*	216*	333*	350*	200*	274*	240*	140	160*	160*	200*	240*	290*	140	18	-	160*
6	Tues.	230*	182*	225*	≥122	280*	76	245*	216*	140	220*	100	100	200*	250*	80	30	140	20
7	Wed.	104	–	118	93	150	≥ 50	127	113	–	60	20	60	80	330*	140	48	60	–
8	Thurs.	144	–	186*	113	190*	80	≥157	127	–	180*	100	100	160*	330*	180*	–	80	–
9	Fri.	128	106	186*	191*	200*	130	186*	167*	100	–	140	160*	160*	170*	180*	–	120	–
10	Sat.	128	106	181*	181*	270*	176*	196*	162*	120	160*	180*	220*	200*	270*	160	–	130	170*
11	Sun.	124	108	98	93	180*	80	132	74	100	–	–	–	–	230*	160*	–	130	70
12	Mon.	108	86	118	127	150	104	132	108	60	–	–	≥160*	–	280*	250*	–	110	90
13	Tues.	128	82	147	157	130	100	132	152	120	120	160*	480*	140	–	200*	12	124	130
14	Wed.	106	84	127	137	130	110	142	118	120	100	120	180*	140	–	160*	54	100	90
15	Thurs.	168*	126	172*	≥206*	360*	220*	221*	186*	180*	160*	200*	–	≥160*	–	70	84	220*	200*
16	Fri.	100	80	132	≥108	160*	136	132	108	100	–	–	200*	–	–	150	48	110	200*
17	Sat.	106	82	142	137	150	110	147	127	100	–	460*	160*	120	–	160*	36	90	120
18	Sun.	116	90	152	152	190*	140	157	132	120	–	–	–	–	–	150	36	140	110
19	Mon.	140	136	≥167*	142	230*	150	181*	176*	–	180*	180*	180*	≥200*	–	130	–	180*	120
20	Tues.	142	112	181*	152	240*	≥124	250*	157	–	–	120	180*	–	60	90	120	150	110
21	Wed.	160*	142	196*	172*	260*	160*	206*	157	60	140	180*	260*	–	40	50	60	190*	150
22	Thurs.	142	154	≥225*	127	–	64	186*	78	100	–	–	60	–	40	30	24	100	120
23	Fri.	110	84	113	64	–	64	≥ 98	≥ 54	40	100	–	40	–	10	30	24	74	80
24	Sat.	158	122	196*	152	230*	210*	191*	147	40	140	160*	240*	180*	10	30	30	184*	140
25	Sun.	96	82	137	113	140	116	137	59	20	100	100	140	100	10	40	–	110	160*
26	Mon.	122	114	176*	147	220*	150	201*	98	40	≥160*	140	160*	180*	10	160*	–	174*	140
27	Tues.	130	150	191*	≥172*	200*	180*	201*	118	60	140	180*	260*	200*	50	250*	60	190*	220*
28	Wed.	112	110	221*	215*	≥300*	280*	299*	186*	100	220*	260*	500*	340*	140	200*	66	290*	210*
29	Thurs.	132	122	≥225*	157	>170*	180*	216*	196*	–	≥200*	180*	240*	240*	230*	–	24	100	≥320*
30	Fri.	112	124	157	137	–	120	167*	123	20	120	140	–	180*	140	50	6	140	250*
31	Sat.	114	122	172*	–	170*	170*	216*	142	120	160*	180*	180*	200*	140	70	6	140	160*

Notes: 1A = Sterling Park; 1B = South Ramp
* indicates concentration ≥ standard

Table 4 (continued). MAXIMUM DAILY OZONE CONCENTRATIONS, μg/m^3 – AUGUST 1976

		Station Identification																	
		Virginia								Maryland					Washington, D.C.				
		DULLES		FAIR	ENG	ALEX	SHIR	SCOR	McL	GAIT	BETH	SSPR	CHEV	SUIT	MSHS	CLEV	WEL	CAMP	DCG
Date	Day of week	1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Sun.	92	74	108	–	80	90	127	98	40	80	80	100	80	50	110	10	80	40
2	Mon.	–	80	93	98	60	70	118	98	–	80	80	60	600*	40	90	10	74	70
3	Tues.	160*	148	201*	113	130	80	206*	167*	–	160*	–	60	–	70	160*	–	100	130
4	Wed.	172*	136	225*	225*	240*	160*	270*	201*	–	–	160*	200*	260*	70	210*	–	174*	190*
5	Thurs.	–	128	186*	176*	210*	≥110	260*	181*	–	≥200*	120	160*	≥220*	60	–	–	190*	190*
6	Fri.	166*	146	250*	152	180*	120	289*	196*	–	≥280*	180*	≥220*	≥180*	40	–	–	140	170*
7	Sat.	108	84	108	103	110	50	103	59	–	80	40	80	100	10	–	–	90	100
8	Sun.	76	58	98	54	80	40	113	88	80	60	60	40	60	10	–	–	60	40
9	Mon.	80	68	103	83	–	36	103	78	80	60	–	60	60	70	–	–	60	30
10	Tues.	128	124	157	152	120	160*	167	137	–	≥160*	–	140	140	140	–	60	110	110
11	Wed.	130	114	≥162*	225*	240*	170*	225*	181*	140	160*	160*	200*	120	≥220*	–	–	180*	280*
12	Thurs.	194*	162*	245*	–	240*	220*	245*	196*	180*	≥200*	80	140	–	380*	≥240*	≥250*	200*	280*
13	Fri.	198*	160*	260*	≥147	260*	200*	206*	206*	160*	≥200*	200*	260*	–	240*	240*	200*	210*	320*
14	Sat.	208*	170*	225*	137	220*	160*	225*	196*	180*	280*	120	160*	80	210*	250*	230*	180*	300*
15	Sun.	136	114	147	88	140	90	152	127	120	180*	80	80	60	110	140	100	–	280*
16	Mon.	118	106	137	103	90	90	113	113	100	100	100	120	–	100	90	60	90	200*
17	Tues.	102	94	93	98	70	90	98	≥ 83	80	80	80	100	–	80	≥ 80	50	90	160*
18	Wed.	126	124	152	147	≥150	96	157	147	120	–	120	130	100	150	140	60	110	140
19	Thurs.	160*	152	191*	108	180*	90	191*	176*	120	–	80	100	80	170*	150	–	110	180*
20	Fri.	270*	260*	284*	147	210*	110	235*	250*	260*	260*	–	120	140	220*	150	150	140	220*
21	Sat.	208*	180*	304*	245*	310*	310*	314*	230*	200*	260*	200*	400*	≥240*	380*	190*	250*	180*	250*
22	Sun.	182*	158	260*	216*	250*	–	225*	172*	180*	240*	160*	220*	140	200*	90	160*	–	400*
23	Mon.	182*	168*	230*	225*	240*	176*	≥196*	176*	≥200*	220*	≥180*	260*	160*	210*	60	150	240*	180*
24	Tues.	260*	224*	≥314*	216*	≥240*	84	314*	274*	220*	260*	180*	140	160*	140	40	130	200*	210*
25	Wed.	260*	196*	230*	103	240*	170*	265*	196*	≥160*	≥320*	60	160*	140	80	20	80	190*	260*
26	Thurs.	204*	146	152	137	220*	150	201*	152	130	–	–	130	120	180*	40	30	170*	250*
27	Fri.	102	94	98	137	140	90	113	78	60	–	–	–	100	140	10	–	94	200*
28	Sat.	110	102	137	88	130	70	137	≥137	140	220*	20	–	80	10	10	–	80	150
29	Sun.	142	124	142	147	130	110	142	127	80	160*	–	–	80	10	10	–	160*	150
30	Mon.	94	96	103	98	60	64	88	≥ 93	60	80	80	–	40	90	80	–	80	150
31	Tues.	138	118	176*	≥127	160*	110	181*	157	80	180*	120	120	100	170*	180*	90	174*	170*

Notes: 1A = Sterling Park; 1B = South Ramp

* indicates concentration ≥ standard

Table 5. NUMBER OF SITES EQUAL TO OR ABOVE OXIDANT STANDARD

Day	Sites considered		Day	Sites considered		Day	Sites considered	
	All	Selected[a]		All	Selected[a]		All	Selected[a]
June 1	3	3	July 1	3	2	Aug. 1	0	0
2	2	1	2	4	3	2	1	1
3	2	2	3	12	10	3	6	5
4	4	3	4	10	7	4	13	10
5	10	10	5	14	12	5	10	8
6	7	7	6	9	8	6	10	9
7	12	11	7	1	0	7	0	0
8	12	11	8	6	4	8	0	0
9	15	12	9	9	7	9	0	0
10	14	11	10	12	10	10	2	2
11	14	11	11	3	1	11	12	9
12	12	9	12	3	1	12	14	9
13	1	0	13	3	2	13	16	11
14	1	0	14	2	1	14	15	10
15	7	6	15	13	11	15	2	1
16	0	0	16	3	2	16	1	0
17	2	1	17	3	2	17	1	0
18	1	0	18	1	1	18	0	0
19	1	0	19	9	8	19	7	5
20	1	0	20	4	4	20	10	8
21	0	0	21	9	8	21	18	13
22	0	0	22	2	2	22	13	10
23	2	1	23	0	0	23	16	13
24	1	0	24	8	7	24	13	11
25	1	1	25	1	0	25	12	10
26	13	10	26	8	6	26	6	3
27	11	9	27	11	8	27	1	0
28	15	13	28	13	10	28	1	1
29	12	9	29	11	9	29	2	1
30	1	0	30	3	2	30	0	0
			31	9	8	31	8	8

[a] Sites 1 through 12 plus Site 16.

for the same day at neighboring stations. A more complete presentation of meteorological conditions during the June to August period is given on pages 37 and 38 of this report.

A second piece of potentially useful information that can be drawn from Table 4 is the number of days each site recorded the daily maximum concentration within the study area. This information is provided in Table 6.

Table 6. NUMBER OF DAYS SITE RECORDED MAXIMUM CONCENTRATION

		Virginia								Maryland					Washington, D.C.				
Site identificati.		DULLES		FAIR	ENG	ALEX	SHIR	SCOR	McL	GAIT	BETH	SSPR	CHEV	SUIT	MEMS	CLEV	WEL	CAMP	DCG
		1A	1B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
No. of days	All sites	1	0	9	1	17	2	17	0	4	4	2	15	4	18	2	4	1	7
	Selected sites[a]	3	0	13	1	26	2	19	0	7	9	3	16	4				1	

[a]Sites 1 through 12 plus Site 16.

It is immediately clear from Table 6 that the apparent severity of the oxidant problem within an area such as this can depend significantly upon the placement of the monitors. Siting characteristics of some of the monitor locations are described later in this section.

Table 7 gives a frequency distribution of the maximum daily ozone concentration for each of the regular monitoring sites, plus separate distributions for the two Dulles monitors. Again, large differences exist between sites, but no clear-cut geographical pattern is evident. The percent of days on which the standard is equalled or exceeded ranges from 18 percent at the South Ramp site at Dulles International Airport to 59 percent at Fairfax, Virginia and at Bethesda, Maryland. It should be borne in mind that the observation days upon which these percentages and Table 6 are based are not identical from site to site.

Table 7. FREQUENCY DISTRIBUTIONS OF MAXIMUM DAILY O_3 CONCENTRATIONS AT 18 MONITORING SITES DURING JUNE, JULY, AND AUGUST 1976

Site		No. of days	Concentration, μg/m³									
Location	Iden. no.		<160	160 - 179	180 - 199	200 - 219	220 - 239	240 - 259	260 - 279	280 - 299	300 - 319	≥320
			Percent of days									
Virginia												
Dulles	1A	68	66	13	7	6	3	0	5	0	0	0
Dulles	1B	89	82	8	5	3	1	0	1	0	0	0
Fairfax	2	78	41	11	18	4	14	3	4	3	2	0
Engleside	3	88	67	8	5	6	3	5	3	1	0	2
Alexandria	4	88	43	6	7	7	7	11	7	6	2	4
Shirlington	5	91	68	12	4	6	6	0	0	1	1	2
Seven Corners	6	92	43	4	12	12	7	7	9	2	3	1
McLean	7	89	62	11	14	7	3	2	1	0	0	0
AVERAGE			56	9	10	7	6	4	4	2	1	1
Maryland												
Gaithersburg	8	79	71	4	7	9	4	4	1	0	0	0
Bethesda	9	68	41	18	13	7	7	2	3	6	0	3
Silver Spring	10	73	56	11	17	11	0	2	1	0	0	2
Cheverly	11	79	44	15	8	9	6	4	9	0	0	5
Suitland	12	71	52	10	10	10	4	6	3	0	0	5
AVERAGE			53	12	11	9	4	4	3	1	0	3
Washington, D.C.												
Sharpe Health School	13	85	55	6	5	7	6	4	2	2	2	11
Cleveland Park	14	73	73	9	7	4	0	7	0	0	0	0
West End	15	71	77	6	4	4	3	3	0	2	0	1
CAMP	16	85	66	8	14	8	1	1	1	1	0	0
D.C. General	17	64	50	14	6	9	3	5	2	4	2	5
AVERAGE			64	9	7	6	3	4	1	2	1	3

A feature of oxidant behavior that may contribute to an understanding of the relative significance of local precursor emissions, transport, and day-to-day carryover is the diurnal variation in concentration at the various sampling sites. Tables 8 and 9 summarize this variation in an approximate fashion by focusing on the time of occurrence of the maximum daily concentration and the hours of the day when the standard was equalled or exceeded. It is clear from these tables that with few exceptions, concentrations in excess of the standard were confined to the daytime hours between 0900 and 1900 EST, and that maximum concentrations occurred most frequently in the early afternoon. This implies that concentrations at all of the sites are dominated by locally produced ozone, but does not rule out longer range transport of precursors.

Oxidant Levels and Meteorological Conditions

Meteorological indices from local airports are typically considered representative of neighboring urban areas. In an attempt to obtain a similarly broad based index for oxidant levels to facilitate comparisons with meteorological conditions, and also to compare levels in different parts of the study area, the values listed in Table 4 were averaged by geographical area. The results are plotted in Figure 14.

The particular areas represented by each curve can be determined by reference to Figure 2. Although differences among the curves do occur, many features are easily identified from one curve to another. Because of these common features, it seemed appropriate to prepare an average curve. To calculate this average curve, maximum values at all sites except the two most outlying sites, Dulles International Airport (No. 1) and Gaithersburg (No. 8) were used. The resulting curve appears at the top of Figure 15. In Figures 14 and 15, vertical dashed lines have been used to set off individual weeks and to identify weekends.

Daily meteorological conditions have also been plotted in Figure 15 so that obvious associations between wind, radiation, temperature and humidity and

Table 8. PERCENT OF DAYS WHEN MAXIMUM OBSERVED O_3 CONCENTRATION FELL ON INDICATED HOUR

Hour, start time (EST)	Site identification number												
	1A	2	3	4	5	6	7	8	9	10	11	12	16
	Frequency of occurrence, percent of days												
00		2	1	2	3	1	3	8	2	3	1		1
01			2	1	1		2	5	2	5	1		4
02		1	2		4			5		3	1		2
03		1			2			5	2	3	1		1
04		1			3	1	1	5	2	3			1
05			1		3			3	2	1			1
06	1							3	3	1	1		1
07								1			1		
08								1		3	1	1	1
09		1	1					3	2	8	3	3	
10	4	4	2	4	1	3		8	6	15	15	8	2
11	4	13	6	12	2	17	12	8	18	19	27	25	7
12	21	11	18	26	12	17	21	18	36	29	41	45	24
13	16	20	32	34	26	26	20	29	45	44	44	49	38
14	16	33	23	24	20	26	25	37	42	37	34	48	34
15	12	30	21	17	24	18	26	40	34	26	24	31	16
16	15	16	14	15	17	17	12	44	26	19	20	23	15
17	12	14	3	1	15	4	7	29	8	29	8	11	5
18	6	1	1	1	6	1		15	2	1	1	4	2
19	1			1	1		1	4	3		3	3	
20	1	1	1			2	1	1	2		3	1	1
21			1		1			1			3		
22			1					1			1	1	1
23			2					1			1	3	
Number of days with observations	68	79	87	89	89	90	87	78	62	73	79	71	85

Table 9. PERCENT OF DAYS WHEN O_3 CONCENTRATION EXCEEDED STANDARD ON INDICATED HOUR

Hour, start time (EST)	Site identification number												
	1A	2	3	4	5	6	7	8	9	10	11	12	16
	Frequency of occurrence, percent of days												
00				4	1								1
01				2		1							1
02						1							1
03						1							1
04						1							1
05						1							1
06						1							1
07						1		1		1			0
08	1	1	1	2	1	7		1		4	3	3	0
09	3	9	8	4	1	17	5	1	3	8	10	7	2
10	7	25	13	29	2	29	12	6	19	14	22	18	11
11	15	39	22	43	10	43	26	10	24	16	23	30	15
12	22	40	26	48	15	47	28	15	43	29	39	38	26
13	22	47	25	51	20	54	28	19	46	27	39	41	27
14	26	49	22	49	16	49	29	23	40	25	37	38	25
15	19	47	22	42	16	43	24	21	33	19	33	32	14
16	19	43	17	43	12	39	15	19	32	15	23	30	8
17	16	34	13	30	12	28	9	19	16	12	16	18	5
18	10	18	3	16	9	16	1	13	2	3	8	8	1
19	6			8	4	6		1	2			4	
20	3			7		1		1				1	
21				3				1					
22		1		2				1					
23				2				1					
Number of days with observations	68	79	87	89	89	89	87	78	63	73	79	71	85

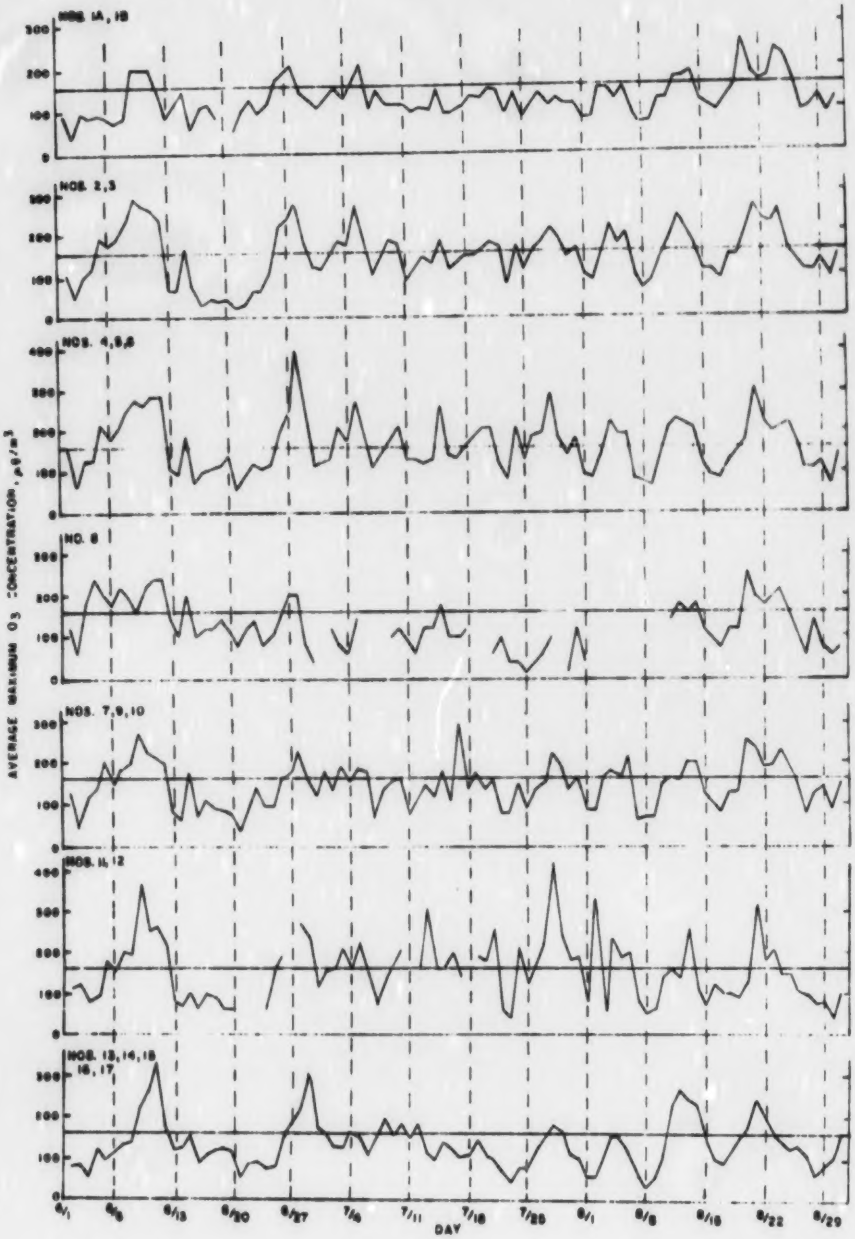


Figure 14. Average of maximum daily O_3 concentrations for selected geographical areas

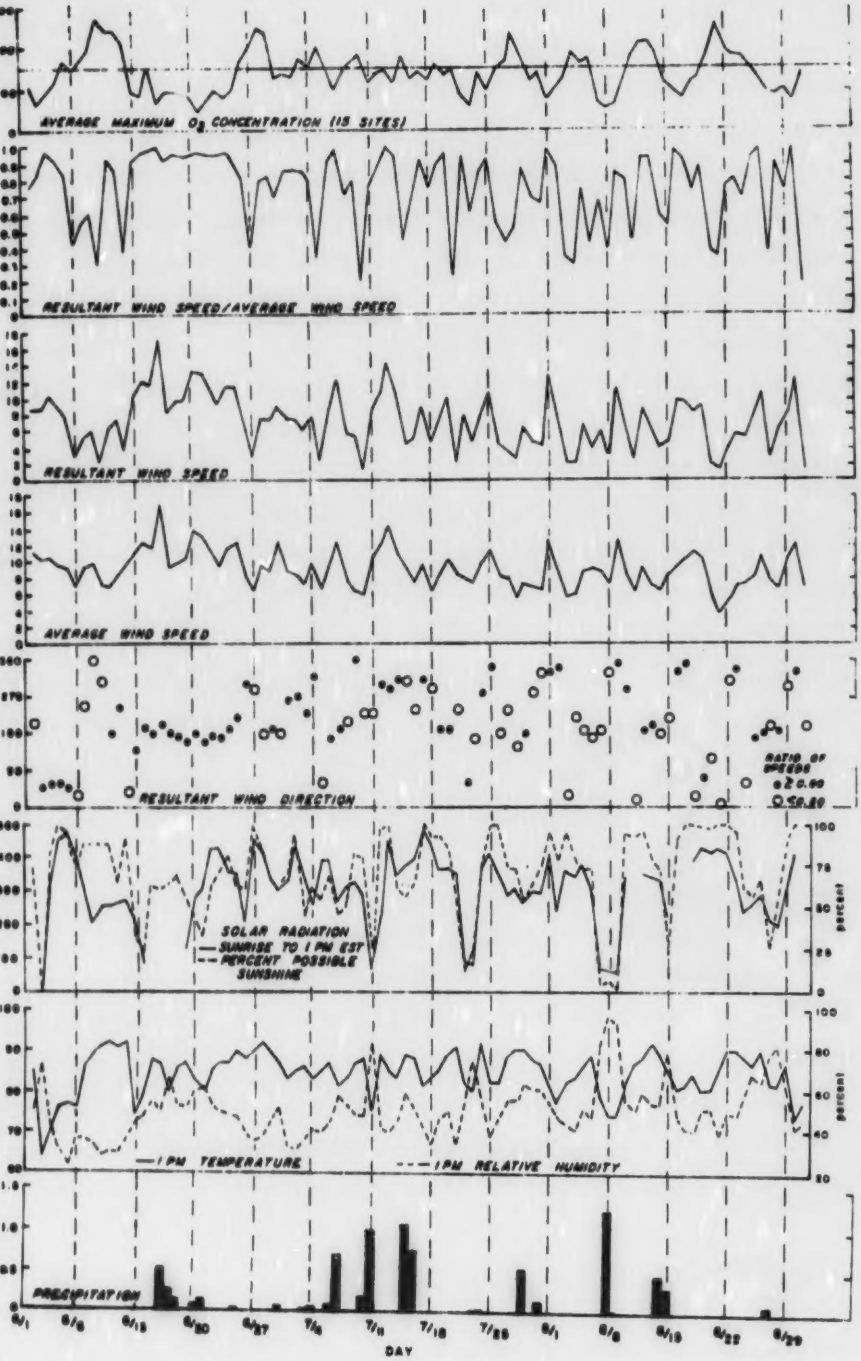


Figure 15. Daily sequence of meteorological parameters and an index of maximum O$_3$ concentration

maximum ozone levels may be detected visually. Four measures of wind speed and direction have been plotted: (1) the average speed during the day, (2) the resultant speed, (3) the resultant direction, and (4) the ratio of the resultant speed to the average speed, which is a measure of the steadiness of the wind direction during the 24-hour period. Two symbols have been used in plotting the resultant wind direction. A filled circle indicates a day when the ratio of resultant to average speed was $\geq$ 0.80, and thus a day when the wind direction was fairly steady, and an open circle, in contrast, indicates a ratio $<$ 0.80 and hence a day with variable wind direction. Two measures of solar radiation are shown. One is the integrated amount of radiation from sunrise to 1300 EST and the other is the percent possible sunshine during the day as reported on the NOAA local climatological data sheet. The temperature and relative humidity at 1300 EST have been used as indices of temperature and moisture, and the amount of rainfall during the 24-hour period as the measure of precipitation. The meteorological data were obtained from National Airport, with the exception of the solar radiation data which were provided by the Alexandria Health Department.

As expected, in a qualitative sense, periods of high ozone concentration tend to be associated with lower than average wind speeds, average or greater than average amounts of radiation, and higher than average temperatures. Other researchers have identified these same meteorological conditions as being associated with high ozone levels.[3-9] The longest period with maximum concentrations averaging below the standard occurred from the 16th to the 25th of June when steady winds of above average speed prevailed from the south, and precipitation occurred on 6 of the 10 days.

Traffic Volume Versus Oxidant Level

The only readily available daily traffic count data consisted of that obtained from the three counters mentioned in Section II. The traffic counters at Memorial Bridge operated satisfactorily throughout the 3-month period, but difficulties were experienced at the other two locations.

Daily counts for the period from 0900 to 1600 EDT have been plotted for the Memorial Bridge in Figure 16(a). Counts at the other two locations have been added successively to the Memorial Bridge data in Figure 16(b) and Figure 16(c) on days when the reported counts were not questioned. The dominating feature of the traffic count data is the weekly cycle. Although the extent of the weekend minimum varies substantially at the Memorial Bridge, the cycle becomes more regular with the addition of traffic at the other two locations.

The limited data plotted in Figure 16(c) show that traffic volume is quite constant during the week from Tuesday through Thursday, peaks on Friday, and has a minimum on Sunday. The averages show 78 percent of the midweek traffic volume on Sunday, 95 percent on Monday, 107 percent on Friday, and 88 percent on Saturday. Comparing this weekly cycle of traffic with the observed variation in the average maximum ozone concentration at 15 sites (Figure 15, upper curve), or that within the District (Figure 16, upper curve) shows only occasional agreement, more suggestive of chance than of a causal relationship. Thus, the major changes in ozone levels appear to be related to meteorological effects of synoptic scale rather than to day-to-day changes in emissions.

Day of the Week Comparisons

Because of a weekly cycle in precursor emissions and in the areal distribution of these emissions, an analysis of weekday-weekend differences in ambient concentrations of oxidants and precursors is a logical approach to furthering a basic understanding of the oxidant problem and the likely effects of some control strategies. However, since a major study is underway which addresses this question using east coast data, only a cursory comparison of ozone levels was carried out during this present study. Two indices of ozone concentration were used. One was the number of sites equal to or above the standard, taken from Table 5, and the second was the average of the maximum concentrations measured at 15 of the monitoring

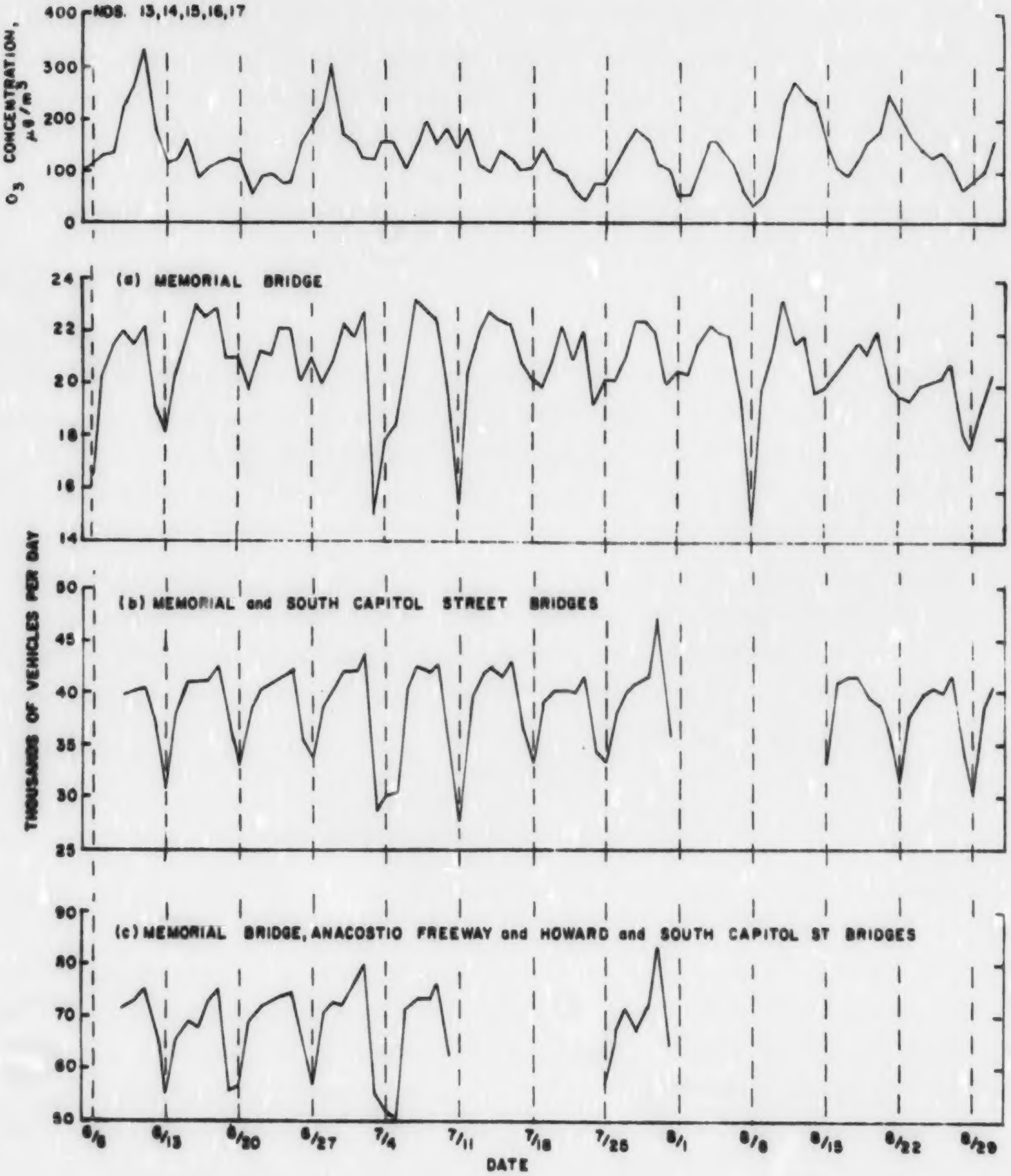


Figure 16. Day-by-day variation in maximum ozone concentration index for Washington, D.C. (upper curve) with variations in traffic counts (lower curves)

sites, used in plotting the top curve in Figure 15. Tabulations of these indices by day of the week are given in Tables 10 and 11. Both indices indicate that the highest average oxidant level occurred on Saturday, and the lowest on Sunday. Of all comparisons made, the only difference that was significant at the 5 percent level was between the number of sites equal to or above the standard on Saturday and on Sunday.

Diurnal Variation of Pollutant Concentrations

The average diurnal variation of ozone for the months of June, July, and August has been plotted for 13 monitoring sites in Figures 17 through 23. When sufficient data are available, diurnal curves are also presented for nitrogen oxides and hydrocarbons in these figures. The diurnal variation of carbon monoxide has been included at six of the sites as a measure of the variation in vehicular emissions. Breaks in the plotted curves indicate hours with less than 10 observations during the month.

Major differences in the magnitude of the average monthly concentrations occur from site to site. Also, even though the diurnal patterns of the pollutants are typical of urban areas and conform to general experience, significant differences do occur among the sites. Some of the more obvious features of the ozone curves are noted below.

The ozone curves, as expected, show maximum concentrations either at 1200 EST or shortly thereafter, and a minimum near 0600 EST at the time of day when convective mixing is being established at low levels and when the morning maximum of NO occurs. Of particular interest are differences in the behavior of average concentrations at different sites. For example, it would seem that a basic understanding of the behavior of oxidants in the Washington, D.C. area must account for such major differences in average peak concentrations as those which occur among the five sites to the southwest of Washington, D.C. (see Figures 17, 18 and 19). At these five sites, peak values are quite consistently high at Massey, Seven Corners, and the Alexandria Health Department, but substantially lower at

Table 10. AVERAGE OF THE MAXIMUM OZONE CONCENTRATION MEASURED AT 15 INDIVIDUAL MONITORS BY DAY OF THE WEEK, µg/m^3

	Day of week						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			118	71	95	120	176
	153	181	201	279	252	251	221
	104	92	164	77	99	101	97
	93	50	83	107	88	102	179
	212	257	248	135	144	139	185
	161	213	154	104	153	166	190
	125	148	156	122	189	135	151
	136	170	149	159	96	63	149
	104	151	174	249	191	133	150
	81	109	131	199	174	184	79
	62	68	135	194	224	225	198
	127	108	89	126	139	188	272
	210	194	193	168	146	109	98
	114	85	148				
N	13	13	14	13	13	13	13
Ave.	129	140	153	153	153	147	165
σ	45.4	61.4	43.5	63.4	51.7	53.3	53.4

Period of record: June 1 through August 31, 1976.

Table 11. NUMBER OF SITES EQUAL TO OR ABOVE OXIDANT STANDARD BY DAY OF WEEK

	Day of week						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			3	2	2	4	10
	7	12	12	15	14	14	12
	1	1	7	0	2	1	1
	1	0	0	2	1	1	13
	11	15	12	1	3	4	12
	10	14	9	1	6	9	12
	3	3	3	2	13	3	3
	1	9	4	9	2	0	8
	1	8	11	13	11	3	9
	0	1	6	13	10	10	0
	0	0	2	12	14	16	15
	2	1	1	0	7	10	18
	13	16	13	12	6	1	1
	2	0	8				
N	13	13	14	13	13	13	13
Ave.	4.0	6.2	6.5	6.3	7.0	5.8	8.8
σ	4.58	6.36	4.43	5.98	4.90	5.34	5.82

Period of record: June 1 through August 31, 1976.

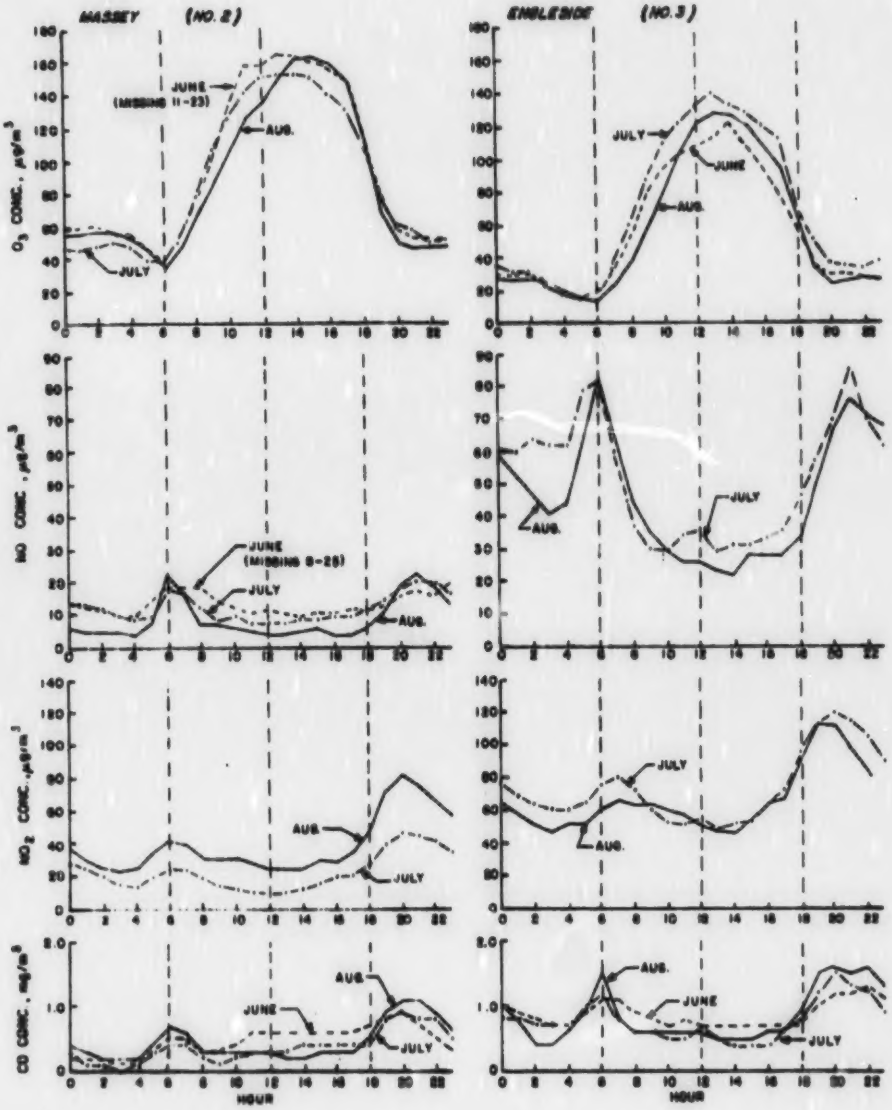
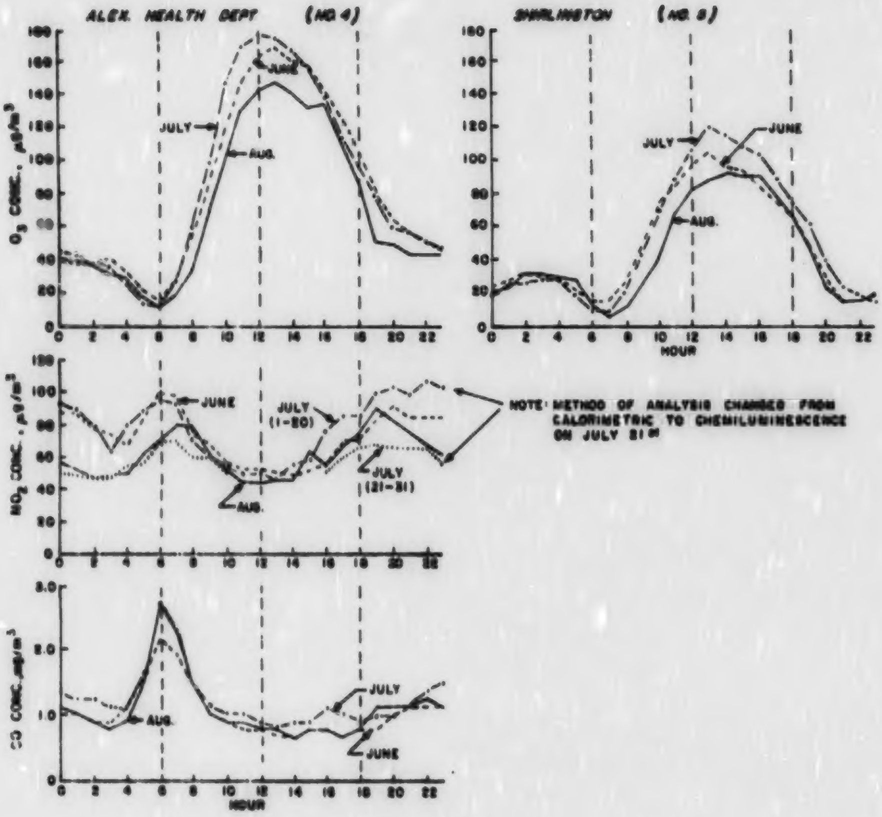


Figure 17. Diurnal variation of pollutants during June, July, and August 1976 at Massey and Engleside



ALEX. HEALTH DEPT (NO. 4)

SHIRLINGTON (NO. 8)

NOTE: METHOD OF ANALYSIS CHANGED FROM CALORIMETRIC TO CHEMILUMINESCENCE ON JULY 21st

Figure 18. Diurnal variation of pollutants during June, July, and August 1976 at the Alexandria Health Department and Shirlington

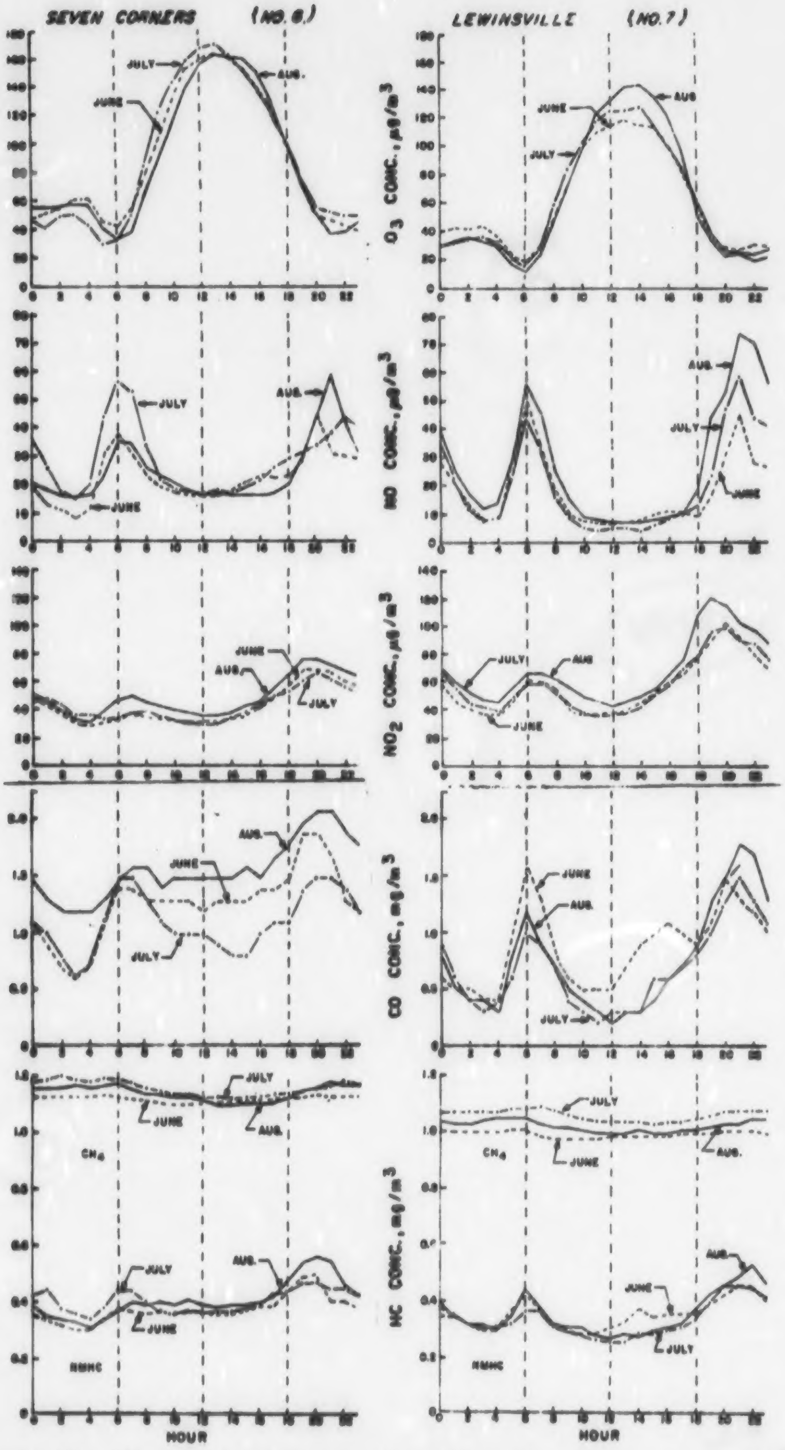


Figure 19. Diurnal variation of pollutants during June, July, and August 1976 at Seven Corners and Lewinsville

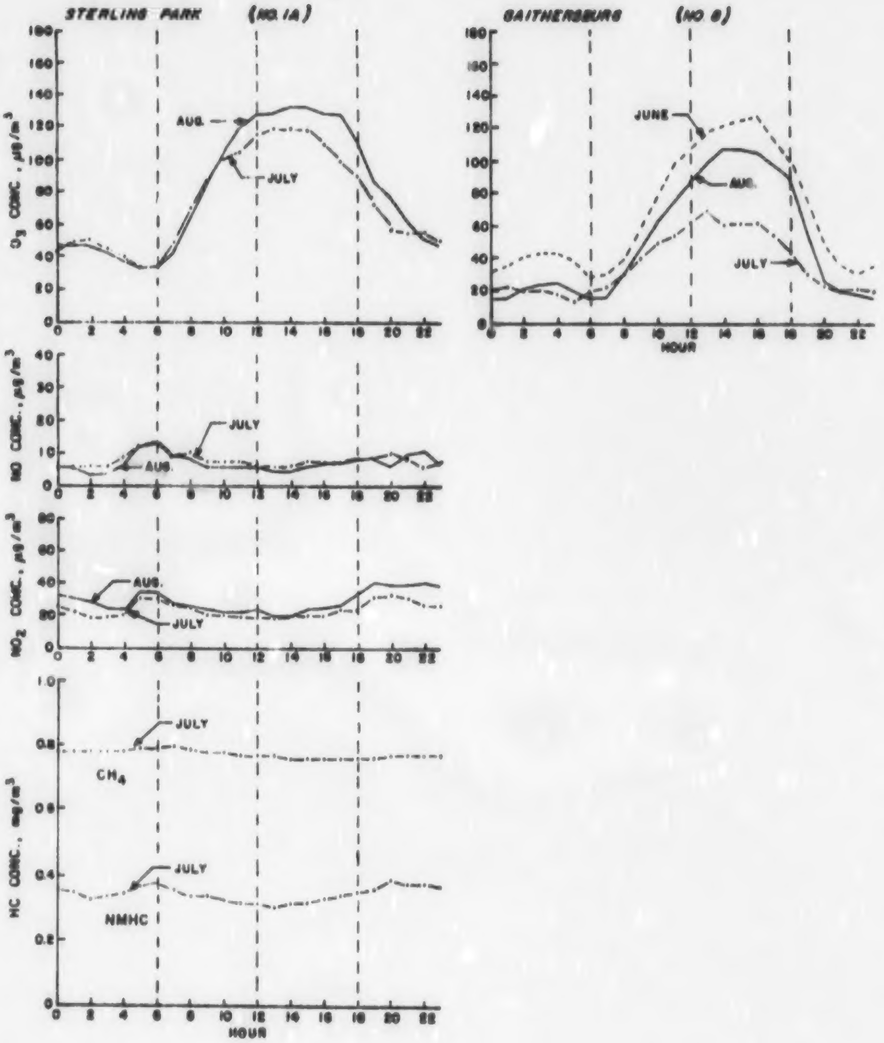


Figure 20. Diurnal variation of pollutants during June, July, and August 1976 at Sterling Park and Gaithersburg

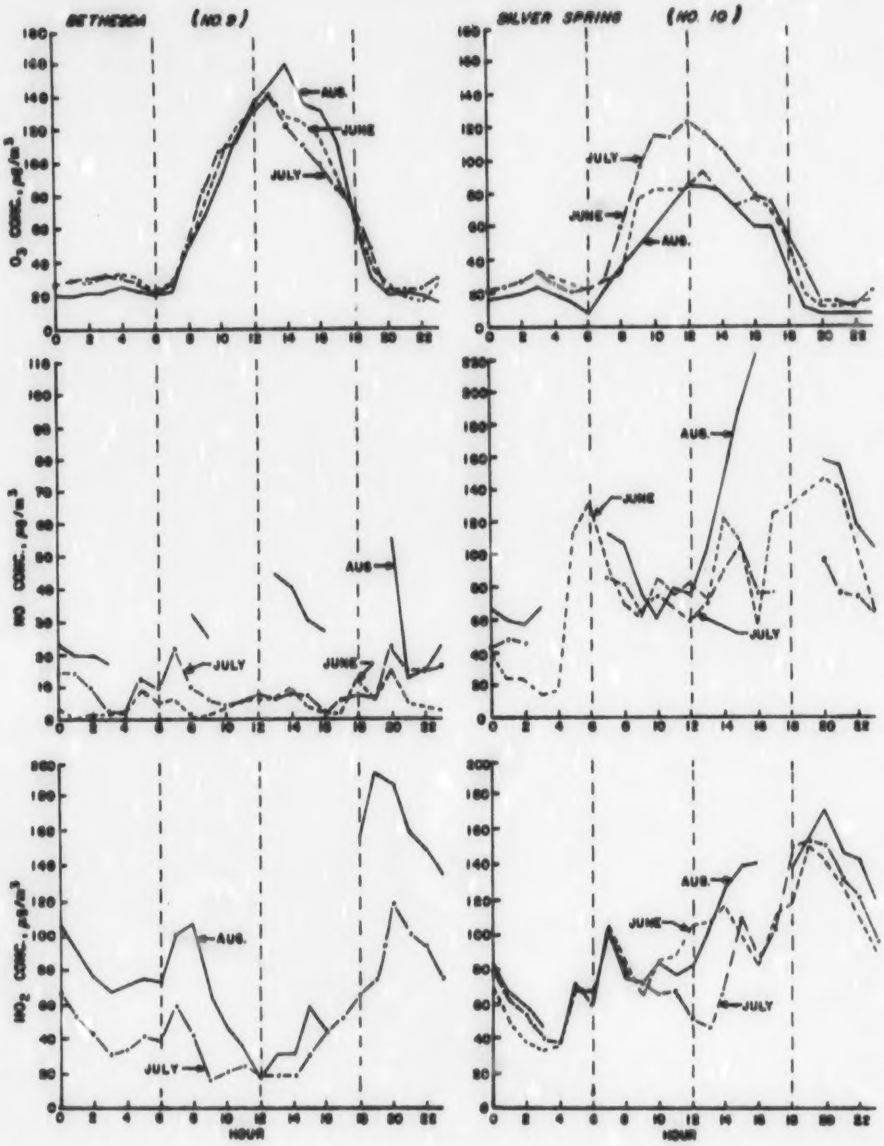


Figure 21. Diurnal variation of pollutants during June, July, and August 1976 at Bethesda and Silver Spring

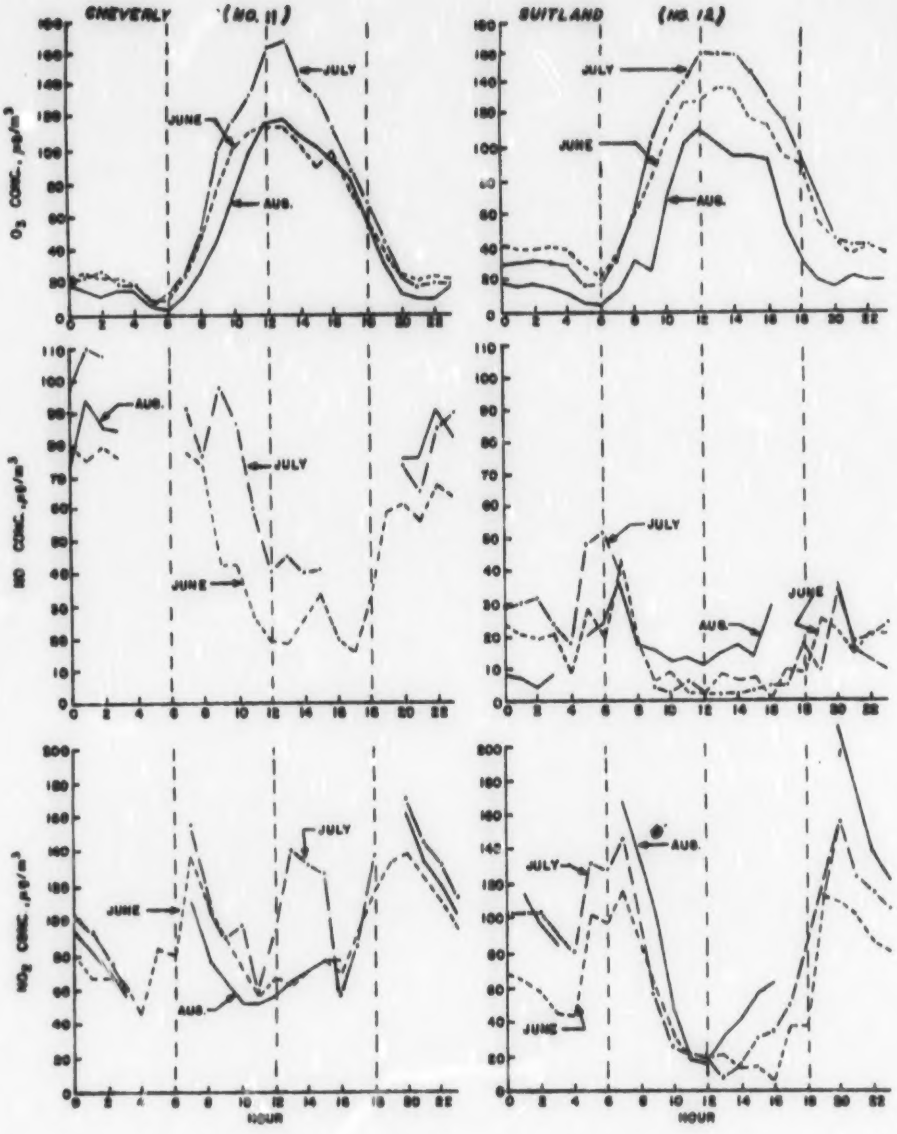


Figure 22. Diurnal variation of pollutants during June, July, and August 1976 at Cheverly and Suitland

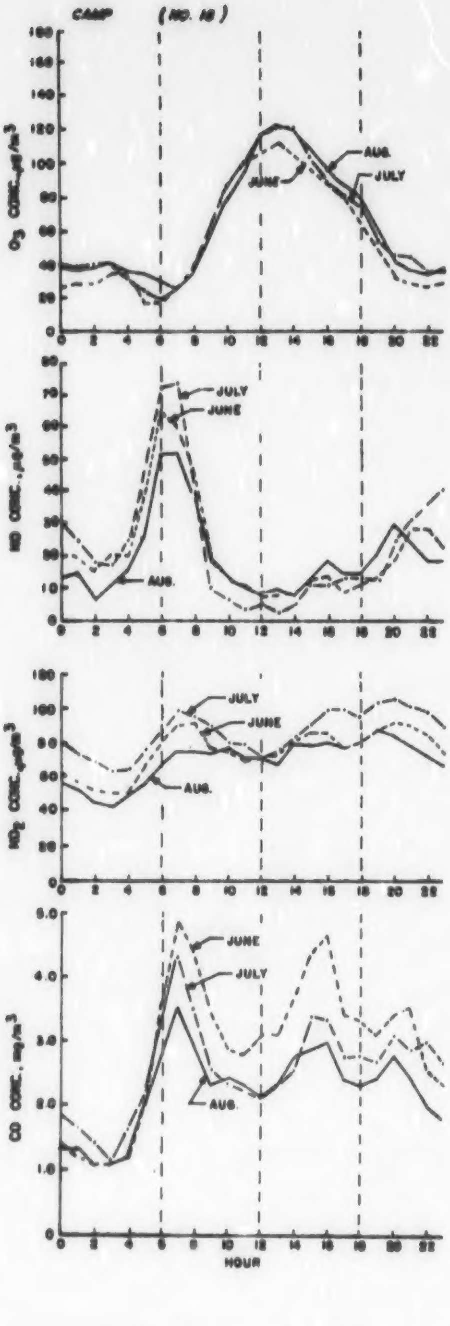


Figure 23. Diurnal variation of pollutants during June, July, and August 1976 at the CAMP station in Washington, D.C.

Shirlington and Engleside. A probable cause for these differences is discussed below under "Influence of Monitor Siting." Another feature of the curves which might hold some clue to oxidant behavior is the variation from month to month at stations to the north and east of Washington (see Figures 20, 21, and 22).

Peak concentrations taken from the average monthly curves shown in Figures 17 through 23 are given in Table 12 where they are used to order the various sites according to the magnitude of the oxidant levels. This ranking can be compared with the frequency of violations data obtained from Table 7 and included as the last column in Table 12.

INFLUENCE OF MONITOR SITING

As pointed out earlier in this section, major differences in ozone concentrations are observed at neighboring stations within the monitoring network. One of the possible explanations for these differences is in the amount of ozone scavenging brought about by nearby vehicular emissions of NO. This explanation is strongly supported by a review of the monitor locations. Specifically, the last sites in Table 12, where the sites were ranked according to the severity of the oxidant problem, are near major traffic sources. Details of monitor location and traffic flow have been provided by the local agencies and/or by site visits by GCA personnel. Written communications from the agencies are included as Appendix D. Briefly, the Silver Spring probe is about 10 to 15 meters due north of Route 495; the Gaithersburg monitor is near a busy intersection where carbon monoxide concentration rises and falls with the traffic; the Shirlington monitor is near I-95; the Engleside monitor is about 24 meters northwest of Route 1; and the CAMP station is in downtown Washington near a parking garage.

Figure 24 was originally prepared to see if the maximum 1-hour ozone concentration at stations outside of Washington was higher than normal when the morning wind direction was from downtown Washington. Unfortunately,

Table 12. THIRTEEN MONITORING SITES ORDERED BY MAGNITUDE OF OXIDANT LEVELS

Site		Peak conc. taken from ave. monthly diurnal curves,[a] μg/m^3				% days when conc. ≥ standard
GCA no.	Designation	June	July	Aug.	Ave.	
6	Seven Corners	164	171	164	166	57
4	Alex. Health Dept.	169	177	147	164	57
2	Massey	165	153	163	160	59
9	Bethesda	141	141	161	148	59
12	Suitland	137	161	110	136	48
11	Cheverly	114	169	118	134	55
7	Lewinsville	119	128	143	130	38
3	Engleside	121	140	128	130	33
1	Sterling Park	–	120	133	(126)	34
16	CAMP	112	122	124	119	35
5	Shirlington	104	120	92	105	32
8	Gaithersburg	128	69	108	102	29
10	Silver Spring	94	124	84	101	44

[a] Figures 17 to 23, Pages 44 to 51.

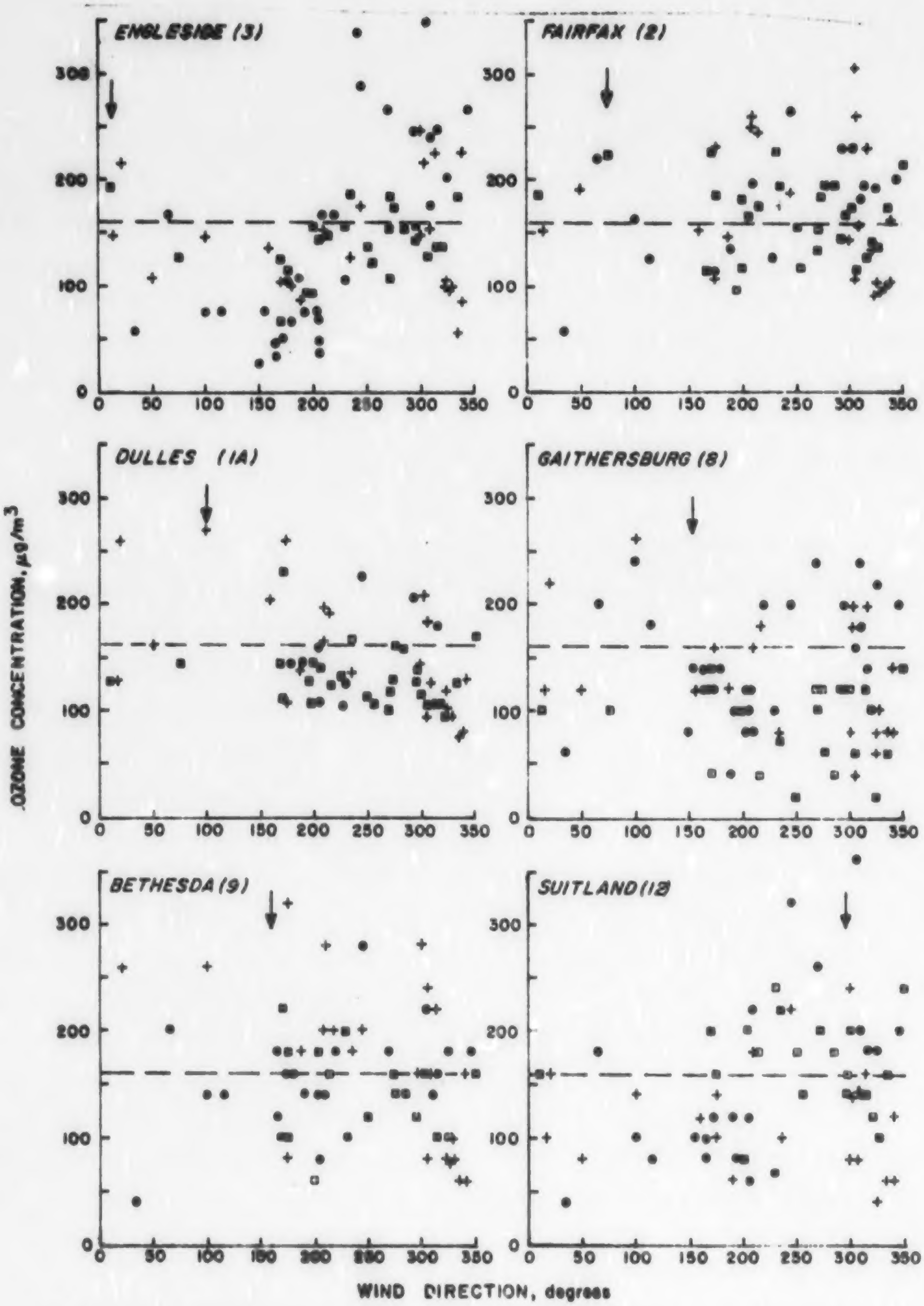


Figure 24. Maximum 1-hour ozone concentration as a function of morning wind direction at selected sites outside the central metropolitan area. (Months are indicated by the symbols: ● = June; ▣ = July; and + = August.) Arrows indicate direction when site is downwind from downtown Washington

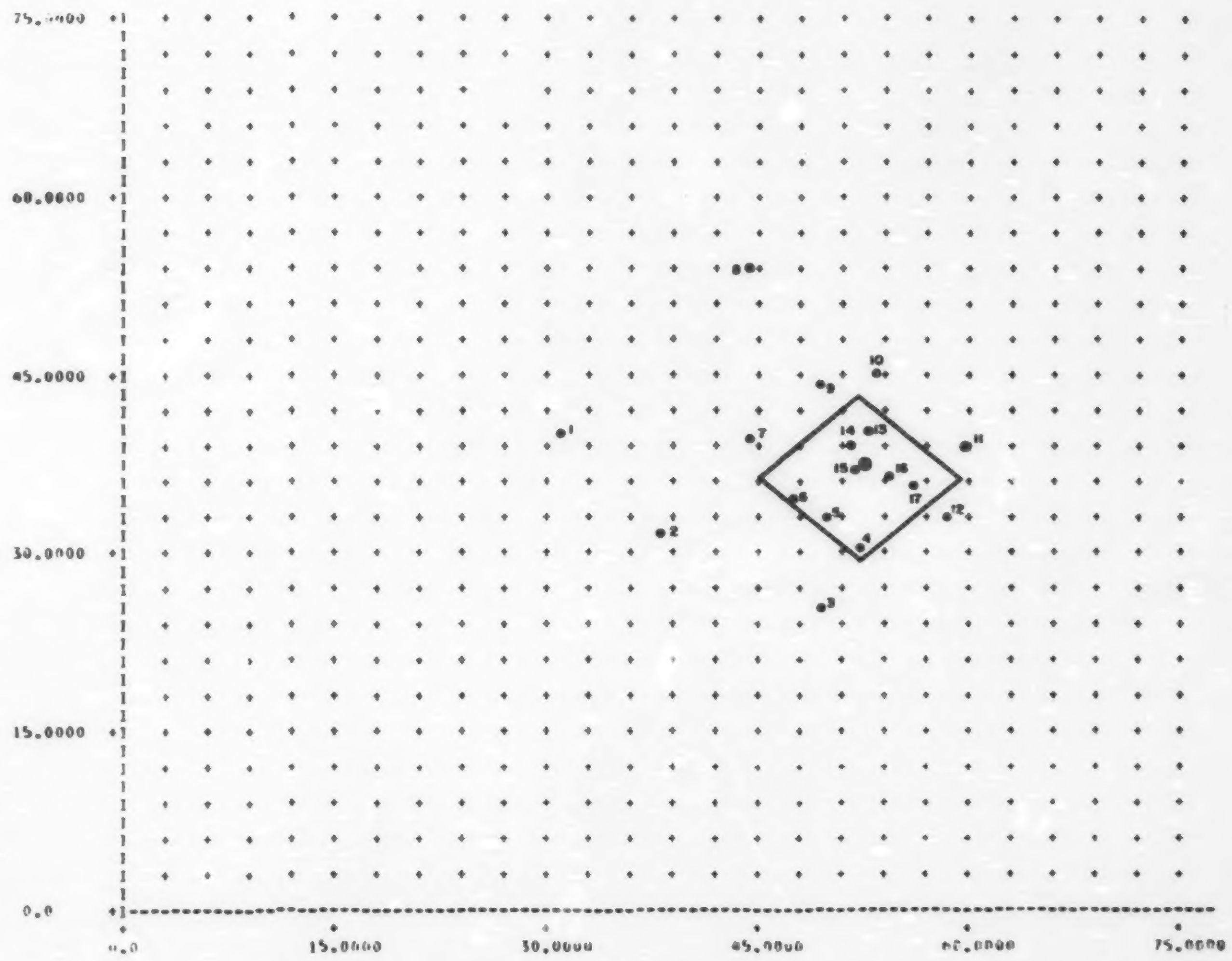
as can be seen from the plots, the winds rarely blew from the city toward five of the monitors, so the figure does not fulfill its intended purpose. It does, however, show at least one example of depressed oxidant levels when the monitor is downwind from a highway, the most striking example of this being at Engleside where southeast winds are associated with low concentrations, and northwesterly winds are associated with high concentrations.

COMPARISON OF UPWIND/DOWNWIND CONCENTRATIONS

It was hoped that some additional insight into the mechanism of oxidant formation in the region might be gained by comparing concentrations and the time of the occurrence of the daily maximum at upwind and downwind sites of the densely emitting Washington area. To determine the upwind and downwind sites, flow within the AQCR was defined by the use of daily trajectories based on surface wind data from National and Dulles International Airports and the local agencies (see Figure 3).

The trajectory calculations were carried out using the trajectory subroutine of the DIFKIN model, adapted to calculate trajectories within the 75-mile square grid shown in Figure 25. (Note that the x and y scales of the grid are not identical.) Figure 26 shows the computer plot of a trajectory for 5 June 1976 as an example. Hourly positions are indicated by the sequence of letters from A to L. The trajectory itself is hand drawn to the letters. The calculation was performed so that the trajectory would pass over a central point in Washington, D.C., arbitrarily chosen to be at the intersection of 16th and U Streets, N.W., at 1400 EST. Similar trajectories for each day of the 3-month period are provided in Appendix E.

The results of these upwind/downwind comparisons are shown in Figure 27. In preparing Figure 27a all days which had a well-defined flow of air, as shown by the trajectories, were selected, and the upwind and downwind sites identified. The average concentration at each hour of the day


75.0000
60.0000
45.0000
30.0000
15.0000
0.0
0.0
15.0000
30.0000
45.0000
60.0000
75.0000
1
2
3
4
5
6
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16
17

Figure 25. Seventy-five mile square grid for use in trajectory calculations. Numbered locations are ozone monitoring stations (see Table 2)

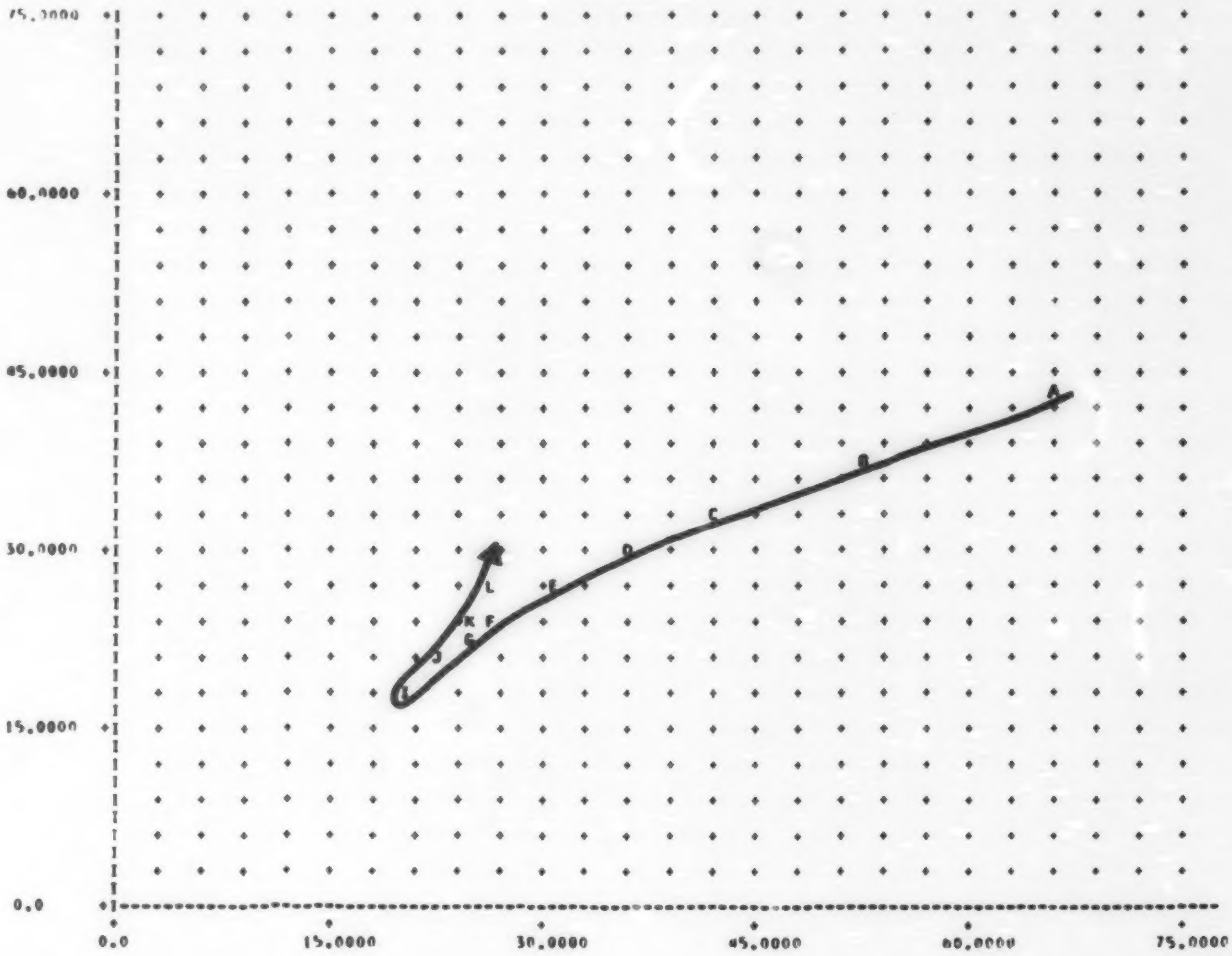
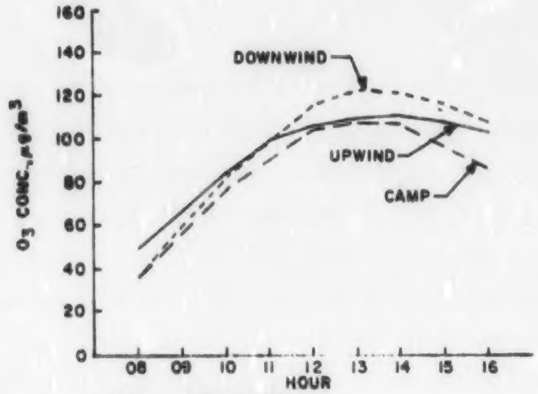
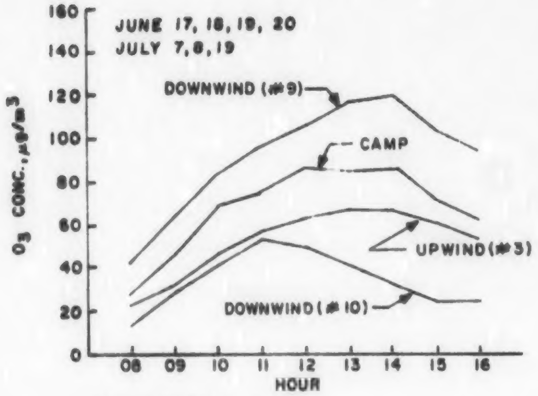


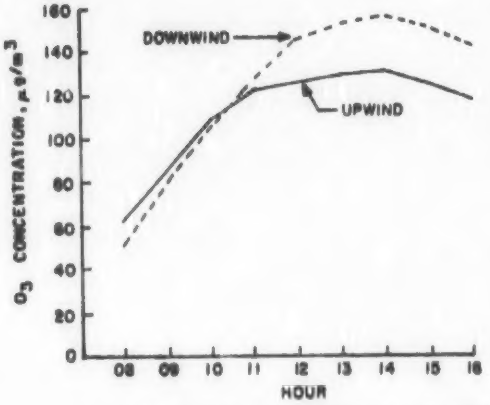
Figure 26. Computer-calculated trajectory for air parcel passing over Washington, D.C. (Point B) at 1400 EST on 5 June 1976



(a) ALL DIRECTIONS



(b) SOUTHERLY FLOW



(c) ALL DIRECTIONS, SELECTED MONITORS

Figure 27. Comparison of average ozone concentrations observed from 0800 to 1600 EST at upwind, downwind, and CAMP stations

from 0800 until 1600 EST was then calculated and plotted. Similar averages were calculated for the CAMP station. For the 27 days with a well-defined wind field, downwind concentrations during the middle of the day averaged about 10 $\mu g/m^3$ or 10 percent higher than the upwind concentrations.

In Figure 27b, concentrations on seven of these days when Station No. 3 (Engleside) was upwind and Station Nos. 9 and 10 (Bethesda and Silver Spring) were downwind were treated similarly. The results appear to reflect local influences rather than differences due to location relative to the central city. Recall that Silver Spring is just north of Route 495, and Engleside is northwest of Route 1.

In Figure 27c, the same 27 days used in preparing Figure 27a were used again but the data from the last six sites in Table 9, judged to be the most influenced by local traffic or other local sources, were eliminated. The resulting curves show downwind concentrations from noon on that are about 20 to 25 $\mu g/m^3$, or nearly 20 percent, higher than upwind concentrations.

One should not rule out the possibility that these differences are a fortuitous result of the particular combination of sites used. This cautionary note is suggested because a comparison of the highest upwind 1-hour concentration to the highest downwind 1-hour concentration observed on the same day showed higher upwind concentrations on 10 of the 27 days investigated.

SECTION V

SUMMARY OF SELECTED AIRCRAFT FLIGHT DATA

This section provides a brief description of the three-dimensional field of ozone in and about Washington, D.C. on selected days during the latter half of August 1976. The descriptions are based on the aircraft measurements made by the EPA Air Quality Branch of EMSL-Las Vegas. Table 13 summarizes the 14 flights made during the aircraft sampling program, and Figure 28 shows the "spiral" locations where vertical soundings were made. Data from these flights were provided GCA on tapes, and computer plots of the ozone and NO/NO_x data, as available, were prepared. These plots were used in conjunction with the ground-level observations made by the local agencies to select the data to be presented in this report. It was hoped that the Washington urban plume might be identified, and that perhaps local and transport influences could be distinguished.

OVERVIEW OF GROUND-LEVEL OZONE CONCENTRATIONS AND ASSOCIATED METEOROLOGICAL CONDITIONS DURING FLIGHT PROGRAM

Figure 29a shows the rapid buildup and decline of ozone levels within the Washington area during the study period. The ozone concentration plotted in Figure 29a is the average of the daily maximum 1-hour values reported at 13 monitoring stations operated by the local agencies. As indicated in the figure, a cold front, with precipitation, passed Washington, D.C. late on the 15th. From the 16th through the 21st, a large high pressure cell, building eastward from the Great Lakes, controlled the weather along the eastern seaboard. The winds at Washington during this period veered from the northwest to the east. The weather map for 0700 EST on August 18th is shown in Figure 30. The pressure pattern became ill-defined on the 22nd

Table 13. SUMMARY OF AIRCRAFT SAMPLING PROGRAM

Flight number	Date	Time, EDT Start	Time, EDT End	Duration, hr:min	Number of spirals	Spiral locations	Approx. flight altitude, m	Flight plan
1	8/17/76	0958	1142	1:44	1	1	670	Twice around Wash. D.C.
2	8/18/76	0853	1051	1:58	4	1,2,3,4	670	Once around Wash. D.C.
3	8/18/76	1610	1851	2:41	5	1,2,4,5,6	670	Once around Wash. D.C. and box S. of Wash. D.C.
4	8/19/76	0922	1134	2:12	4	7,8,9,10	660	Once around Wash. D.C. and box N.E. of Balt.
5	8/19/76	1556	1757	2:01	4	7,8,9,10	660	"
6	8/20/76	0612	0843	2:31	5	7,7,8,9,4	1100	"
7	8/20/76	1604	1803	1:59	4	7,8,9,4	680; 875	"
8	8/21/76	1147	1356	2:09	5	1,7,11,12, 13	670	Box with Wash. D.C. in N.W. corner
9	8/23/76	0612	0930	3:18	1	2,7	720; 340	Wide area N. of Balt., E. to S.E. of Balt. over ocean
10	8/23/76	1611	1640	0:29	1	7	–	Aborted flight N. of Wash. D.C.
13	8/25/76	1501	1644	1:43	0	–	1660; 2000	Wide area box with Wash. D.C. and Balt. in N.E. corner
14	8/26/76	0300	0650	3:50	1	7	610 to 1510	Wide area box with Wash. D.C. and Balt. on S. side
15	8/26/76	1101	1558	4:01	0	–	700 to 2060	Up Atlantic coast to Nantucket and return
17	8/27/76	0855	1140	2:45	0	–	1630 to 2330	South to Raleigh/Durham and return

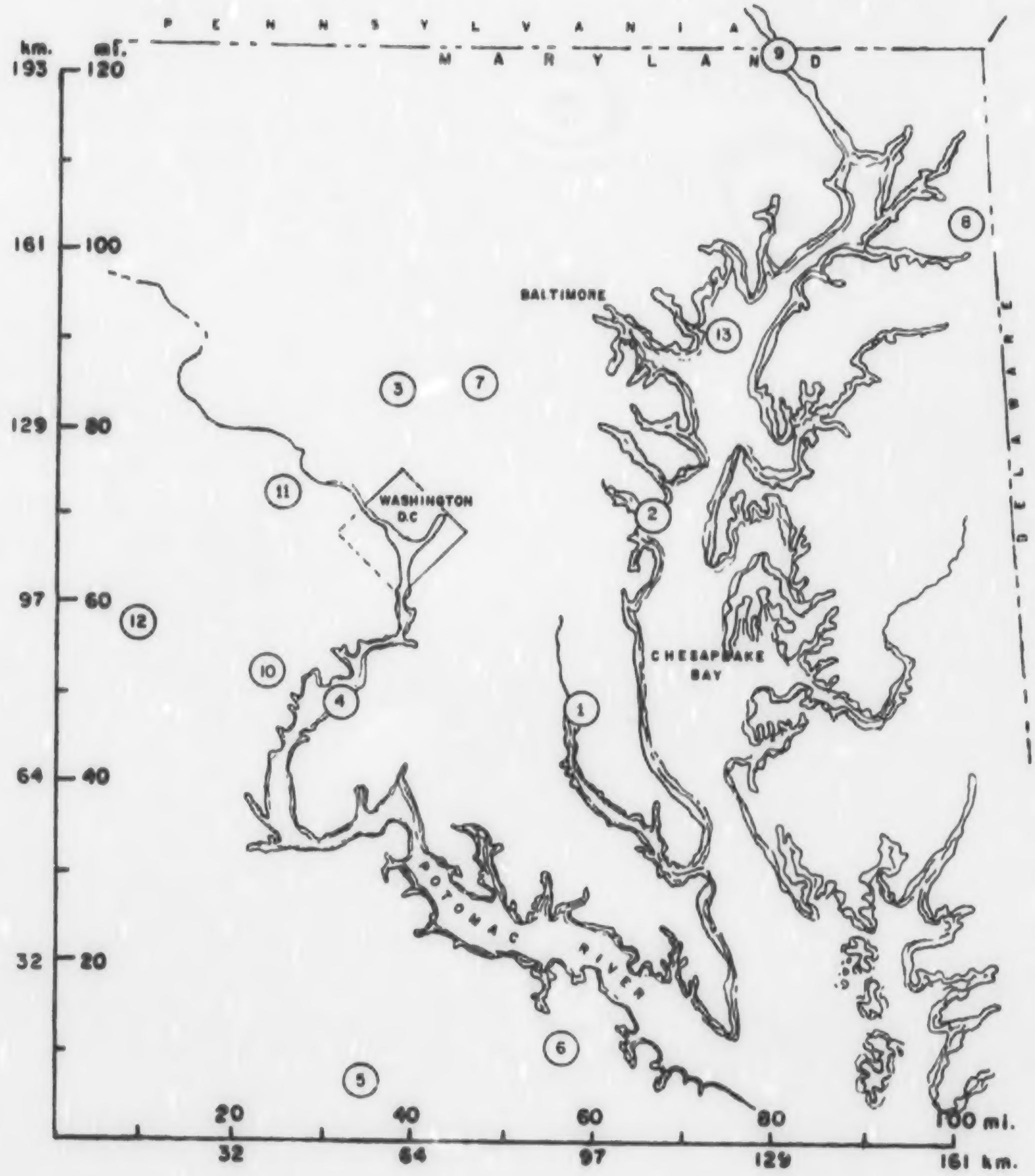
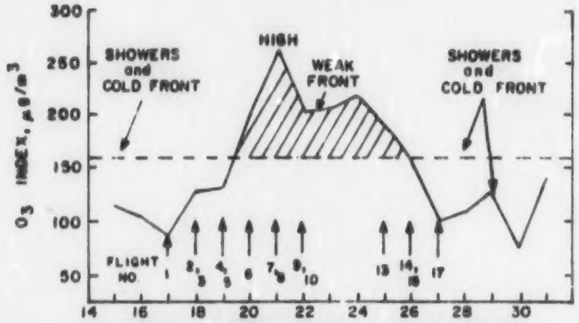
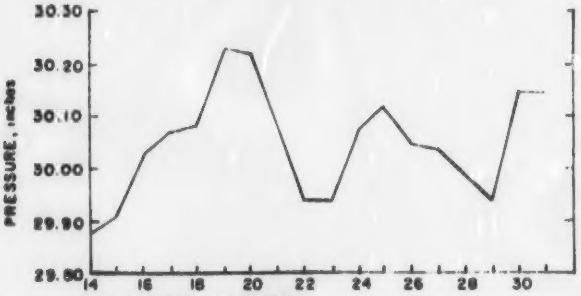

PENNSYLVANIA
MARYLAND
DELAWARE
km.
mi.
193
120
161
100
129
80
97
60
64
40
32
20
BALTIMORE
WASHINGTON D.C.
CHESAPEAKE BAY
POTOMAC RIVER
1
2
3
4
5
6
7
8
9
10
11
12
13
20
40
60
80
100 mi.
32
64
97
129
161 km.

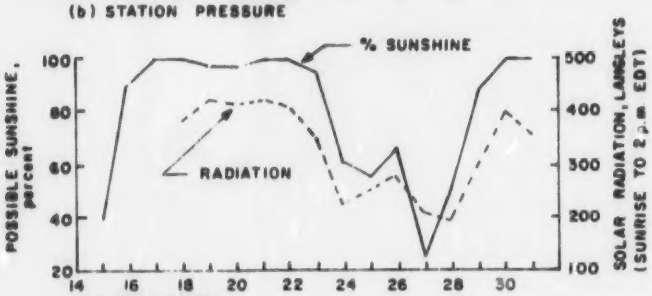
Figure 28. Spiral locations of aircraft soundings during air sampling program



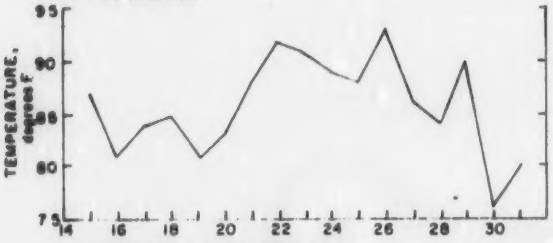
(a) AVERAGE MAXIMUM OZONE CONCENTRATION



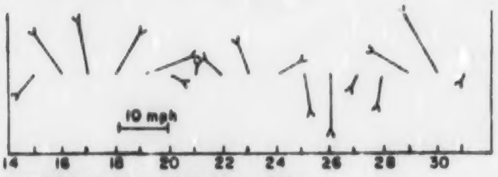
(b) STATION PRESSURE



(c) INSOLATION

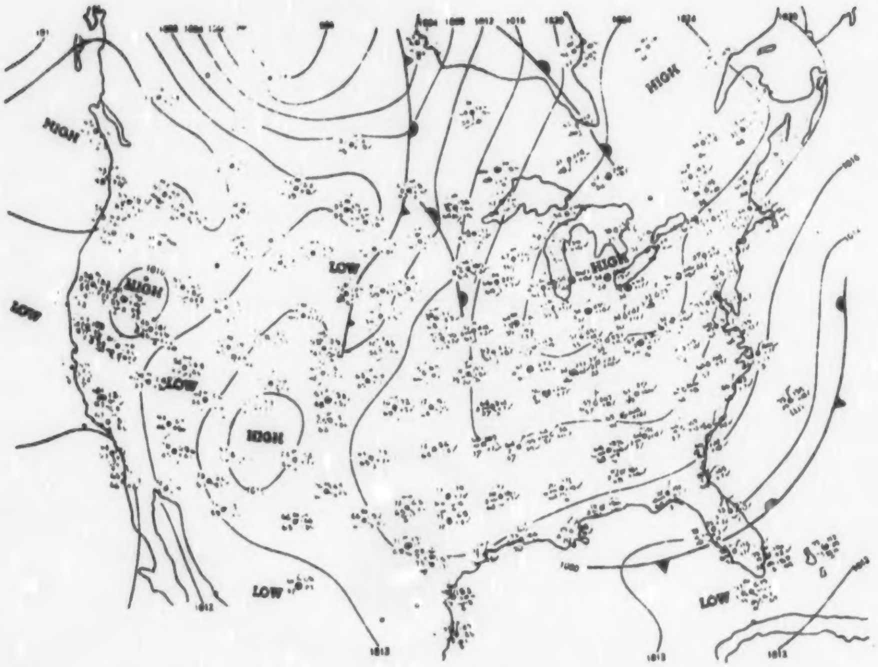


(d) MAXIMUM TEMPERATURE



(e) RESULTANT SURFACE WIND

Figure 29. Daily values of the maximum ozone concentration index (13 station average) and selected meteorological parameters during aircraft sampling program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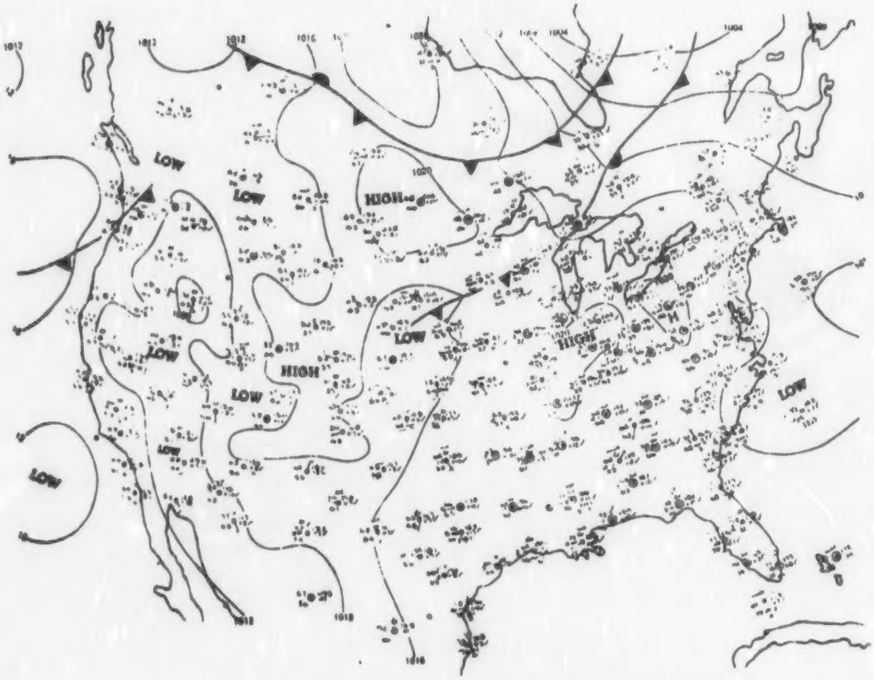
LOW

Figure 30. Surface weather map for 18 August 1976, 0700 EST


LOW
LOW
HIGH
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HIGH
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LOW
HIGH
LOW
LOW
LOW

Figure 31. Surface weather map for 22 August 1976, 0700 EST

under the influence of a coastal low of tropical origin and the approach of a very weak cold front which passed Washington late on the 23rd. This weakening frontal zone was followed by a high pressure cell and ridge line which gradually moved off the coast. Figure 31 shows the weak pressure gradient over the eastern part of the country at 0700 EST on the 22nd, and Figure 32 shows conditions on the 24th. The map for 0200 EST on August 27th (Figure 33) shows the ridge line off the coast and a cold front approaching the Great Lakes. This sharp frontal system, shown in Figure 34, passed Washington on the 29th.

Figure 29 shows the day-to-day changes in several meteorological parameters during the period. Daily average values of the station pressure and the daily maximum temperature at National Airport are shown in Figure 29b and Figure 29d, respectively. Two measures of insolation are plotted in Figure 29c: (1) the percent possible sunshine at National Airport, and (2) the amount of solar radiation received at the Health Department in Alexandria from sunrise to 1400 EDT. The 24-hour resultant wind at National Airport has been indicated by barbs in Figure 29e. The transport wind through the mixing layer, as estimated from the Sterling, Virginia soundings, is given in Table 14, and the midday temperature soundings at Sterling have been plotted at 48-hour intervals in Figure 35.

Examination of the meteorological data shows that the buildup of ozone concentrations is associated with the easterly moving high from the vicinity of the Great Lakes and the development of a strong subsidence inversion over the Washington area.

From the 17th of August to the 21st, the base of the deep, stable layer (see Figure 35) lowered from about 825 to 900 millibars, thus decreasing the depth of the mixing layer by roughly one-half. Also associated with the slowly-moving high pressure cell was a general reduction in wind speeds to near calm conditions, as shown by Figure 29e, and Table 14. Because of the resulting low ventilation rate, pollutants accumulated

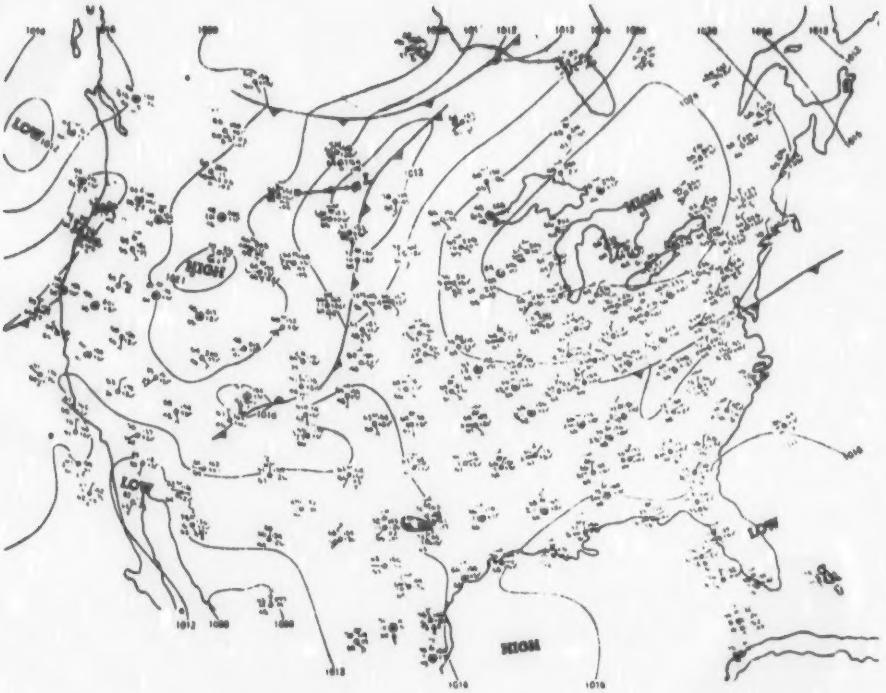
LOW
HIGH
HIGH
LOW
LOW
HIGH

Figure 32. Surface weather map for 24 August 1976, 0700 EST

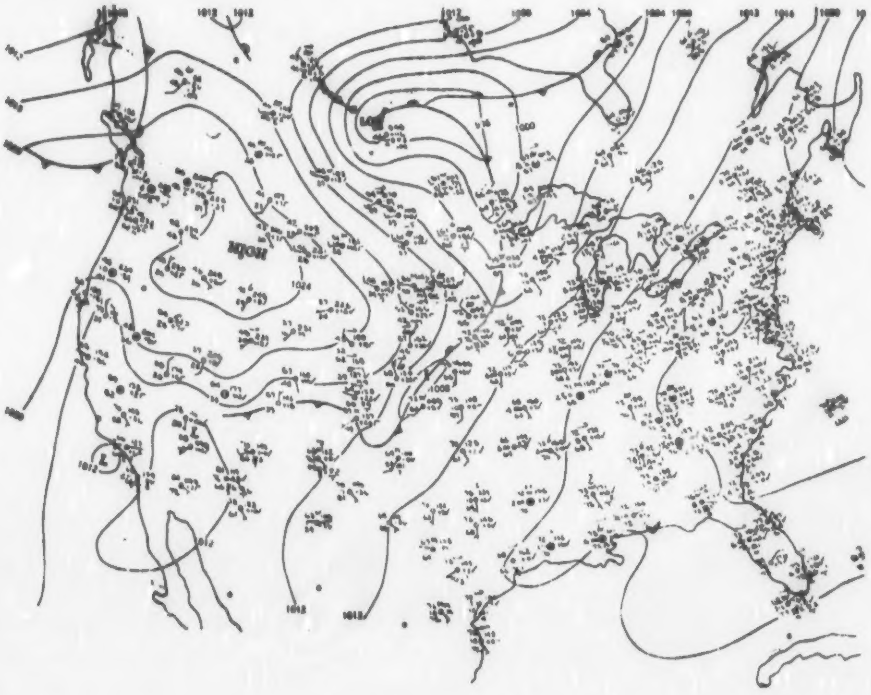

Figure 33. Surface weather map for 27 August 1976, 0700 EST

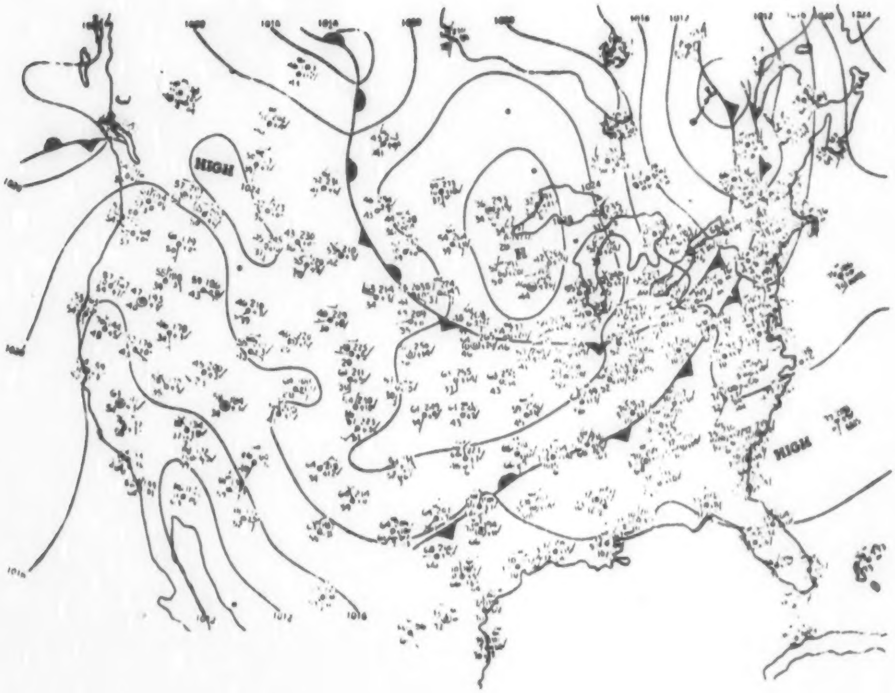

Figure 34. Surface weather map for 29 August 1976, 0700 EST

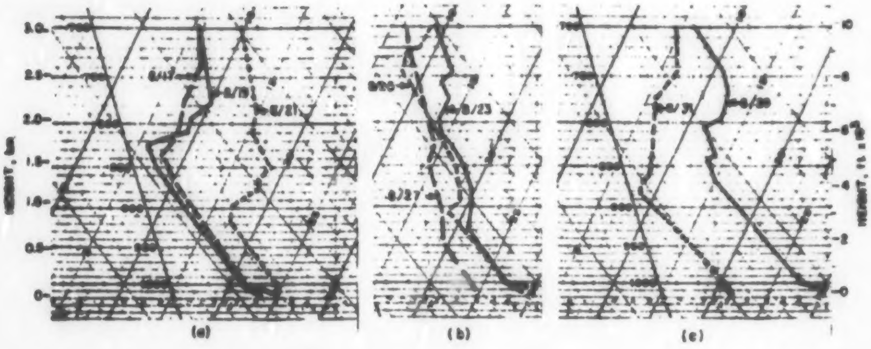

Figure 35. Midday (1300 EDT) temperature soundings taken at Sterling, Virginia during the period 17-31 August 1976. Soundings are plotted on adiabatic charts at 48-hour intervals

Table 14. MIXING LAYER TRANSPORT WIND[a]

	Nighttime, 0700 EDT		Daytime, 1300 EDT	
Date	Direction, deg	Speed, kts	Direction, deg	Speed, kts
8/16			325	14
17	330	6	360	11
18	360	8	30	16
19	30	6	50	10
20	20	2	90	6
21	20	2	90	2
22	240	1	340	6
23	340	5	320	6
24	10	8	20	5
25	210	6	210	6
26	200	3	190	5
27	340	3	360	5
28	320	2	220	4
29	260	1	300	16
30	340	20	340	14
31	20	3	270	6

[a] Estimated from the Sterling, Virginia soundings.

within the general air mass, and, as shown by Figure 29c, were subject to strong solar radiation throughout the daylight periods. With the movement of the second high pressure cell of the period off the coast on the 25th, cloudiness increased, and the winds became southwesterly, then northwesterly, but remained quite light until the passage of the major cold front on the 29th.

Figures 36 and 37 present the low-level trajectories which were calculated for the 18 through 22 August 1976 period. These trajectories show the transport of surface air from the northeast, down from the Baltimore-Philadelphia area, at the start of the period, and the slow, ill-defined but westward drift beginning early in the afternoon of the 20th and continuing through the 21st.

Flight data obtained during the period of ozone buildup was selected as being of most interest, and a series of figures has been included in the text to illustrate the major changes that occurred during this period. Additional figures prepared from the flight data are provided in Appendix F.

Three types of figures are used to describe the concentration fields:

1. A flight track, superimposed on a map of the area, with ozone concentrations and sampling time marked at selected points along the track. For the most part, concentrations plotted along these tracks are the averages of five readings reported at 15-second intervals. The transport wind, as estimated from the Sterling radiosonde data, is shown on the map. Also, a scale to convert the transport wind to travel distance is included on the wind arrow. The locations where vertical profiles were measured are marked as "spirals."

2. A computer plot of individual 15-second data points versus elapsed time in minutes. The points along the flight track at which concentration was plotted in the preceding type figure are keyed to the computer plot by letters of the alphabet. If a letter appears with subscripts, the approximate location was sampled more than once, and the sampling sequence is indicated by the subscripts.

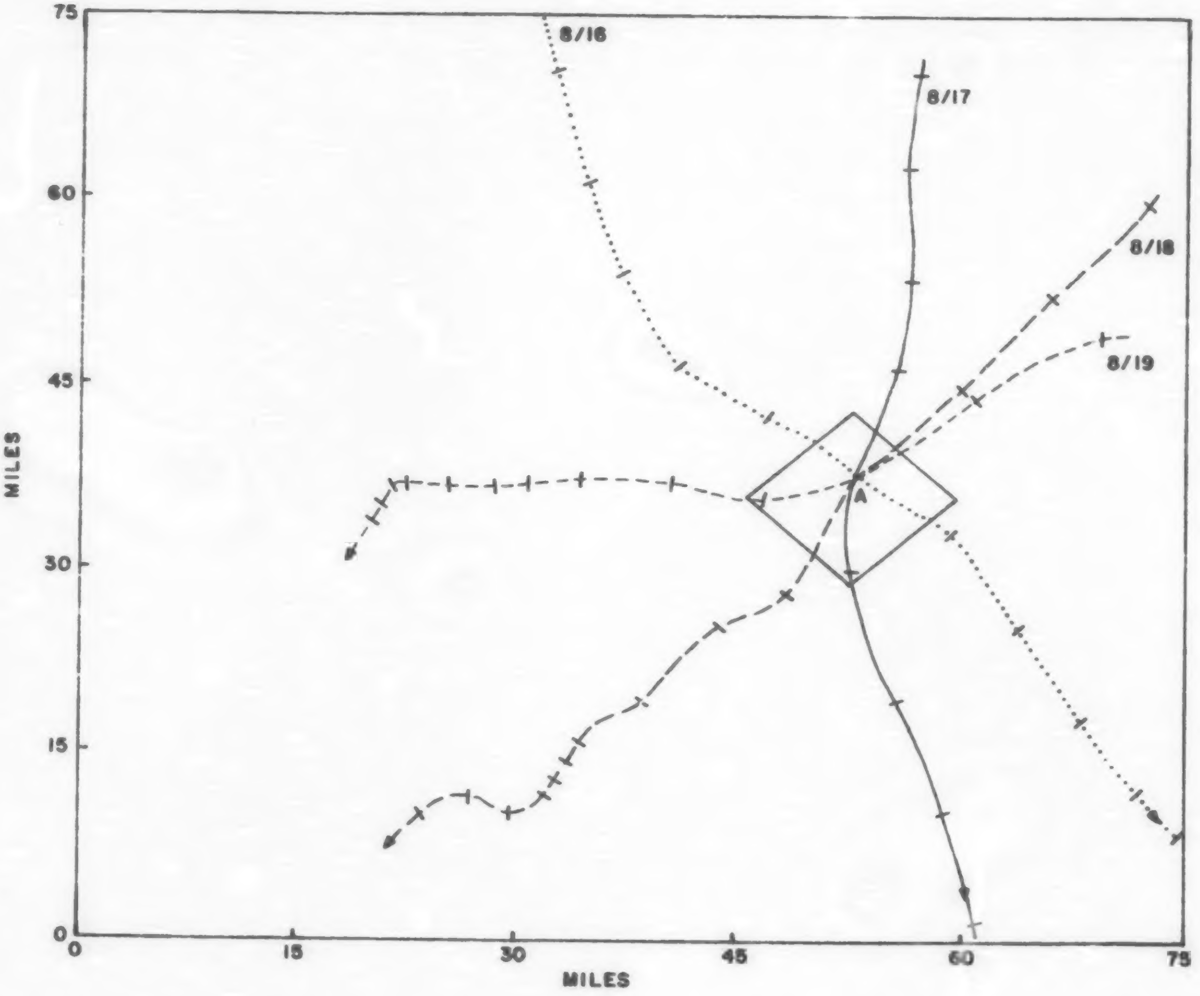

Figure 36. Low-level trajectories of air parcels passing through Washington, D.C. at 1400 EST on 16, 17, 18, and 19 August 1976. Ticks indicate 1-hour transport

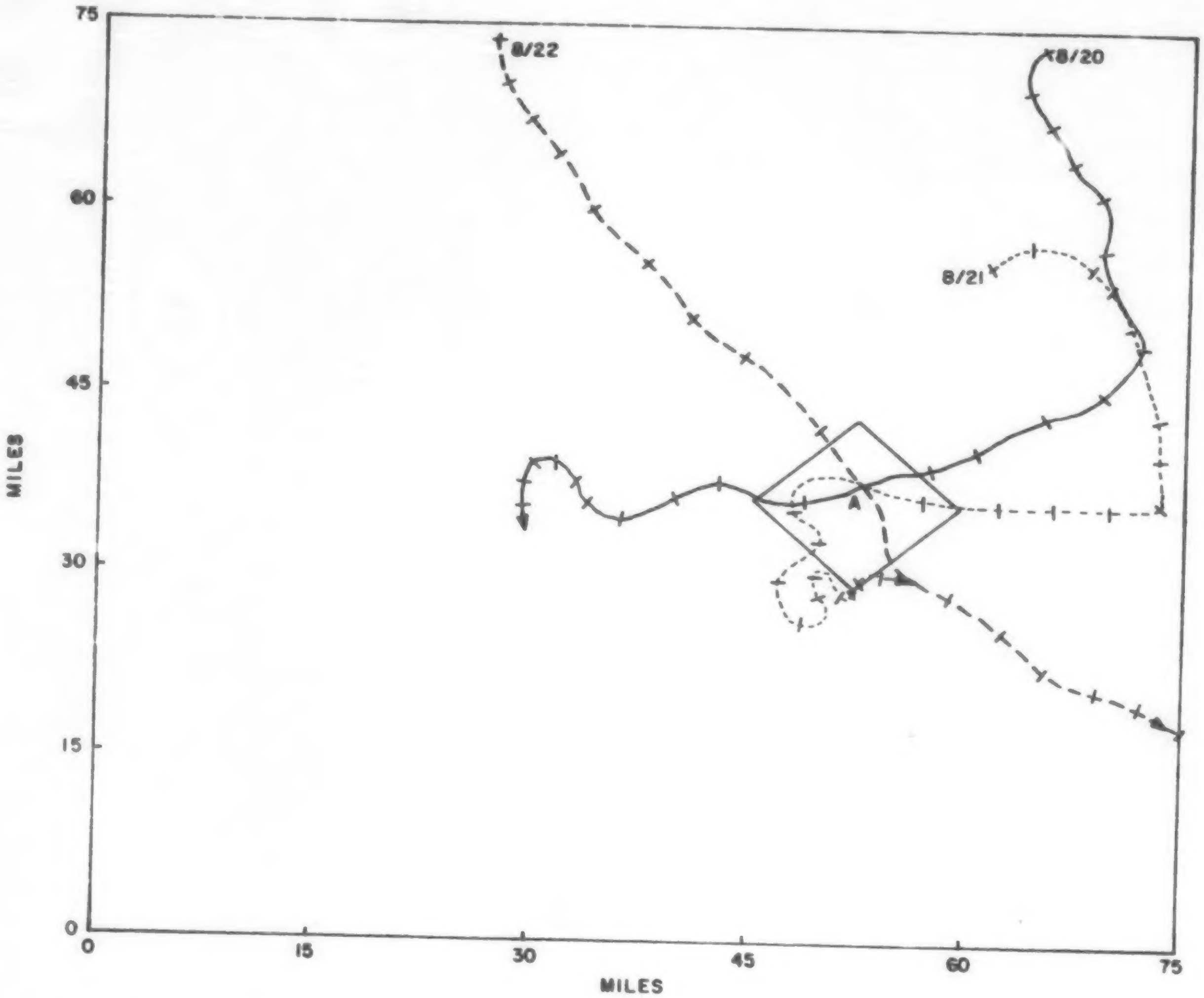

Figure 37. Low-level trajectories of air parcels passing through Washington, D.C. at 1400 EST on 20, 21, and 22 August 1976. Ticks indicate 1-hour transport

3. Computer-plotted profiles of temperature, ozone, and NO/NO$_x$. Individual 15-second data points are plotted as a function of height.

Conditions Prior to the Ozone Buildup (17 to 18 August 1976)

Figures 38, 39, and 40 show the flight tracks on the 17th and 18th of August. All three of these flights were made at an altitude of approximately 670 meters, or 2200 feet. On the mornings of the 17th and 18th, ozone concentrations were about 40 ppb, but increased slightly during the sampling period. On the afternoon of the 18th a longer flight was made that included a box south of Washington as well as the flight path around Washington which had been used on Flights 1 and 2. During this flight, concentrations at the selected points ranged from 75 ppb (Point B) west of Washington to 110 ppb (Point N) measured just prior to landing in Baltimore. Again, the flight altitude was 670 meters. Concentrations increased somewhat with time, and perhaps from west to east, although there was no clear-cut geographical pattern. Figure 41 shows the computer plot of ozone concentration versus elapsed time. This plot shows considerable structure to the ozone distribution, but it is not obvious how this structure relates to ground-level emission patterns. Note that concentrations were near or above the standard during most of this flight. Figure 4 shows the vertical profiles of temperature and ozone measured at spiral location No. 1 during Flight No. 1, and Figure 43 shows the ozone profile at the same location on the afternoon of the 18th. By the afternoon of the 18th the inversion was based slightly below 2 kilometers. The concentration within the stable layer remained at about 0.04 ppm, but between flight level and the base of the inversion the concentration had increased to more than twice that amount. Maximum surface ozone concentrations measured within the study area on the 18th were close to, but did not exceed, the 0.08 ppm standard.

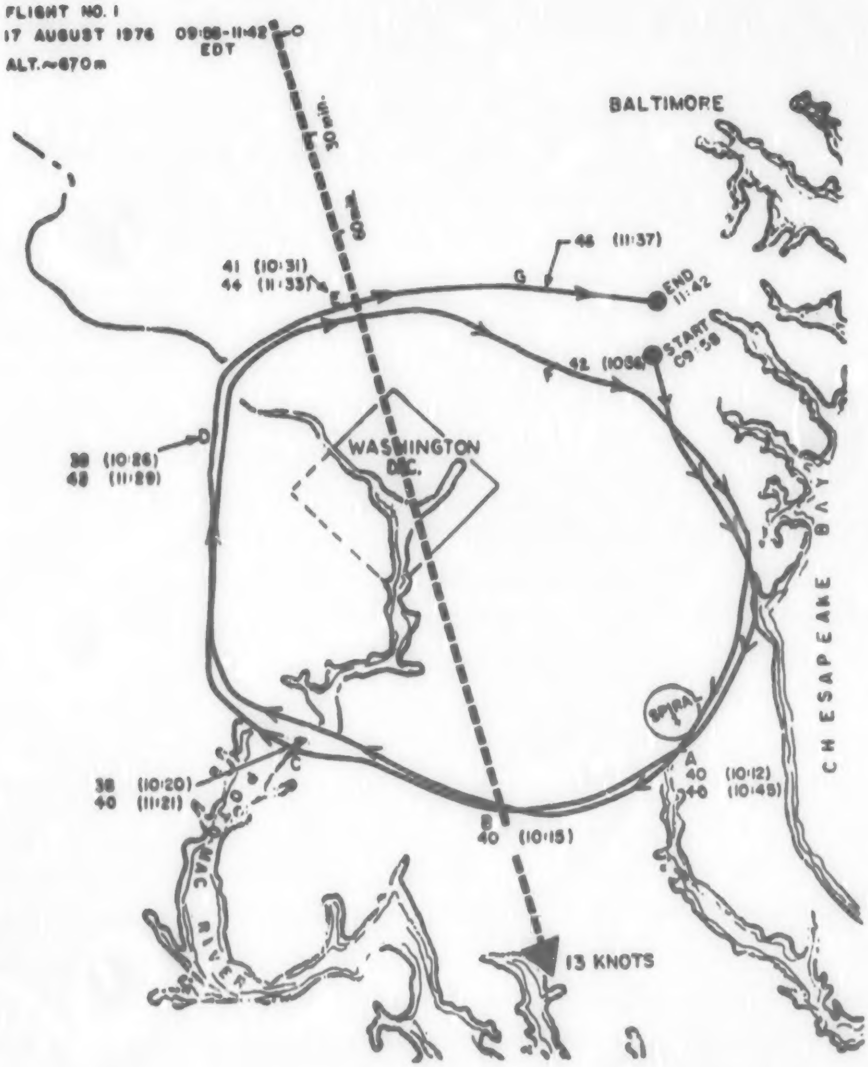
FLIGHT NO. 1
17 AUGUST 1976 09:58-11:42 EDT
ALT.~670 m
30 min.
60 min.
BALTIMORE
46 (11:37)
G
END 11:42
41 (10:31)
44 (11:33)
E
START 09:58
42 (10:36)
F
38 (10:26)
48 (11:29)
D
WASHINGTON D.C.
CHESAPEAKE BAY
SPIRAL
A
40 (10:12)
40 (10:45)
38 (10:20)
40 (11:21)
C
B
40 (10:15)
POTOMAC RIVER
13 KNOTS

Figure 38. Sampling track during Flight No. 1. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

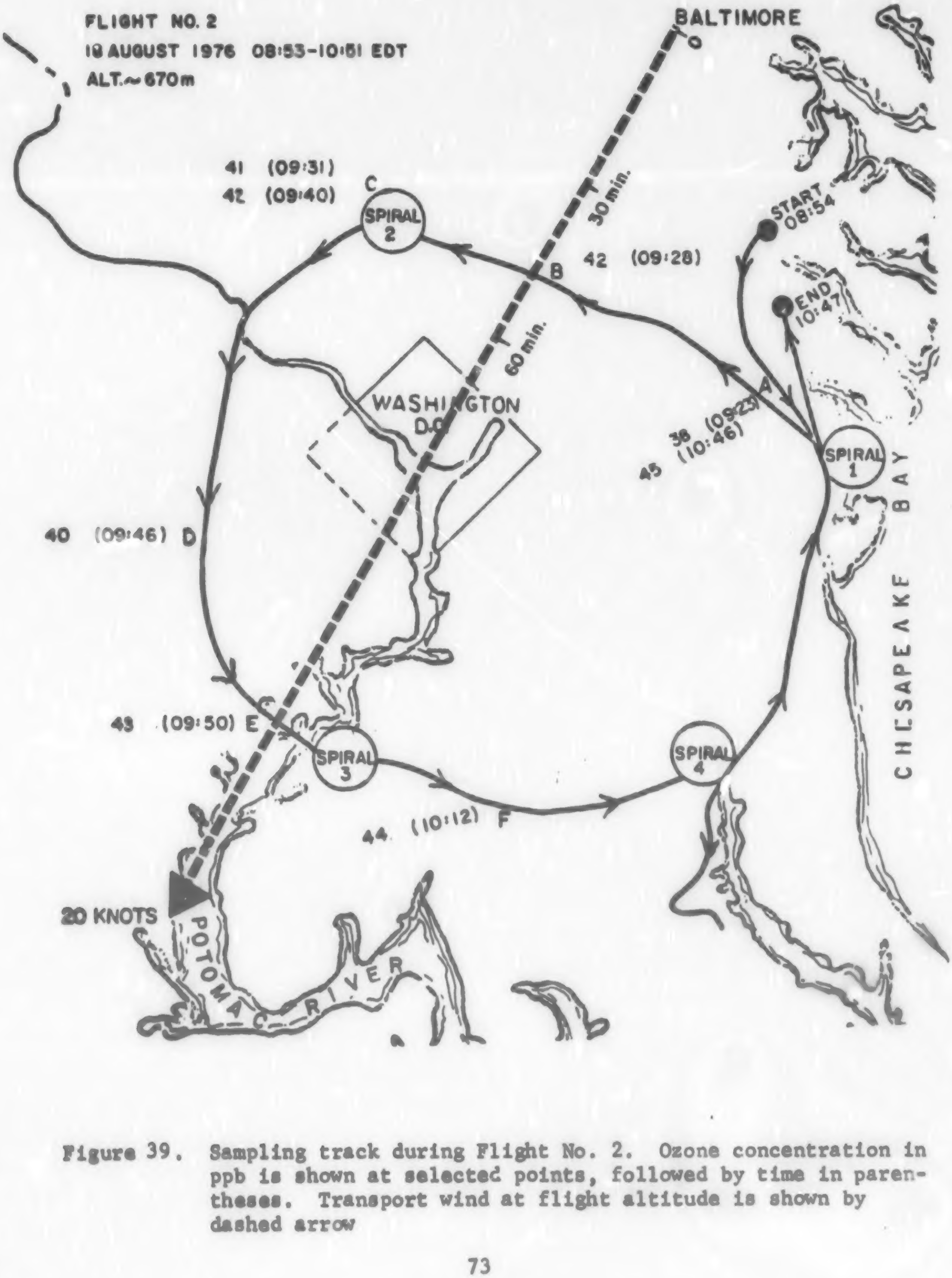
FLIGHT NO. 2
19 AUGUST 1976 08:53-10:51 EDT
ALT.~670m
BALTIMORE
41 (09:31)
42 (09:40)
C
SPIRAL 2
30 min.
B
42 (09:28)
START 08:54
END 10:47
60 min.
WASHINGTON D.C.
A
38 (09:23)
45 (10:46)
SPIRAL 1
CHESAPEAKE BAY
40 (09:46) D
43 (09:50) E
SPIRAL 3
SPIRAL 4
44 (10:12) F
20 KNOTS
POTOMAC RIVER

Figure 39. Sampling track during Flight No. 2. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

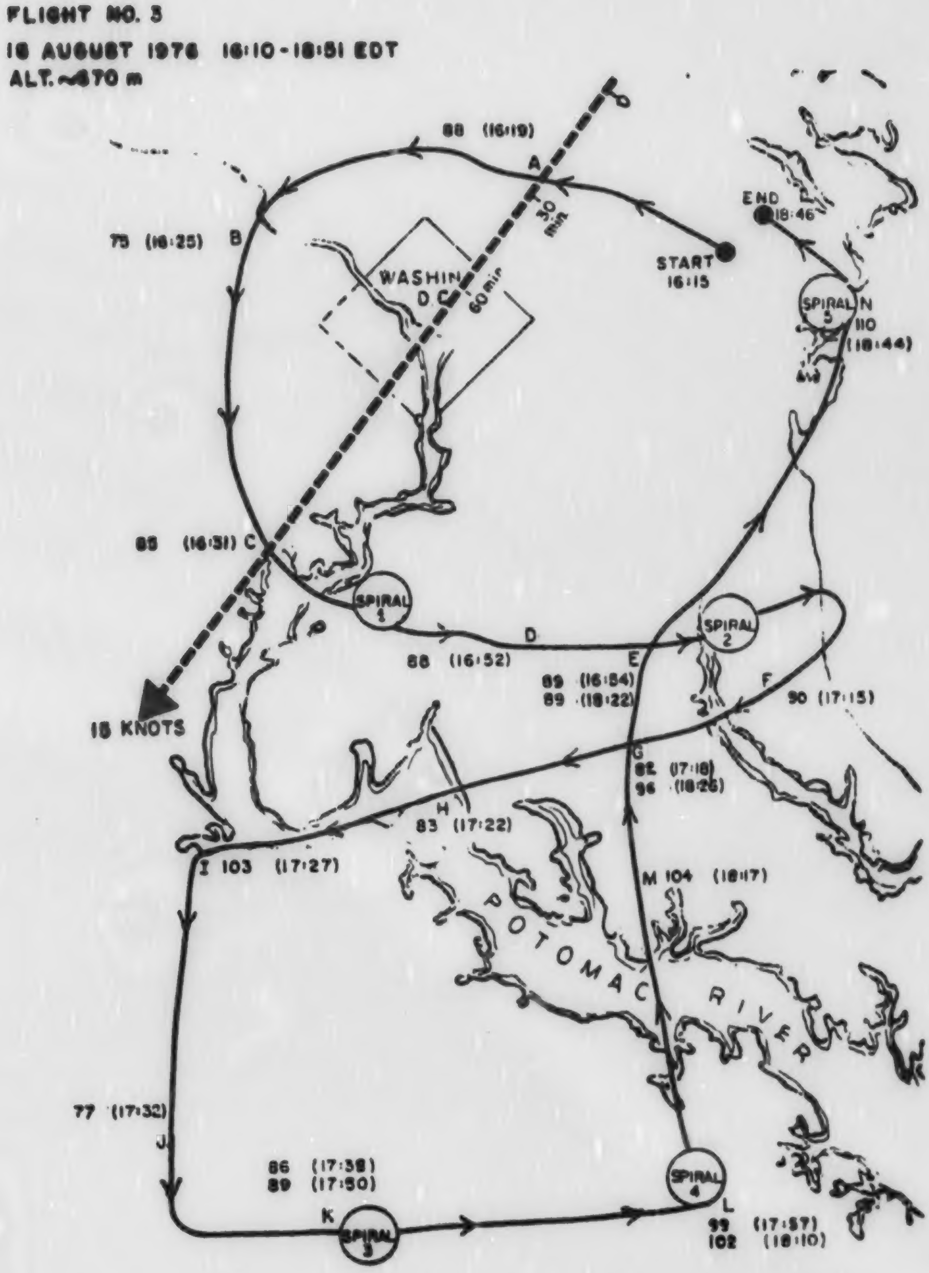
FLIGHT NO. 3
16 AUGUST 1976 16:10-18:51 EDT
ALT. ~670 m
88 (16:19)
A
30 min
60 min
75 (16:25)
B
WASHIN D.C.
START 16:15
END 18:46
SPIRAL 5
N
110 (18:44)
85 (16:31) C
SPIRAL 1
D
88 (16:52)
E
89 (16:54)
89 (18:22)
SPIRAL 2
F
90 (17:15)
15 KNOTS
G
92 (17:18)
96 (18:26)
H
83 (17:22)
I 103 (17:27)
M 104 (18:17)
POTOMAC RIVER
77 (17:32)
J
86 (17:38)
89 (17:50)
K
SPIRAL 3
SPIRAL 4
L
99 (17:57)
102 (18:10)

Figure 40. Sampling track during Flight No. 3. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

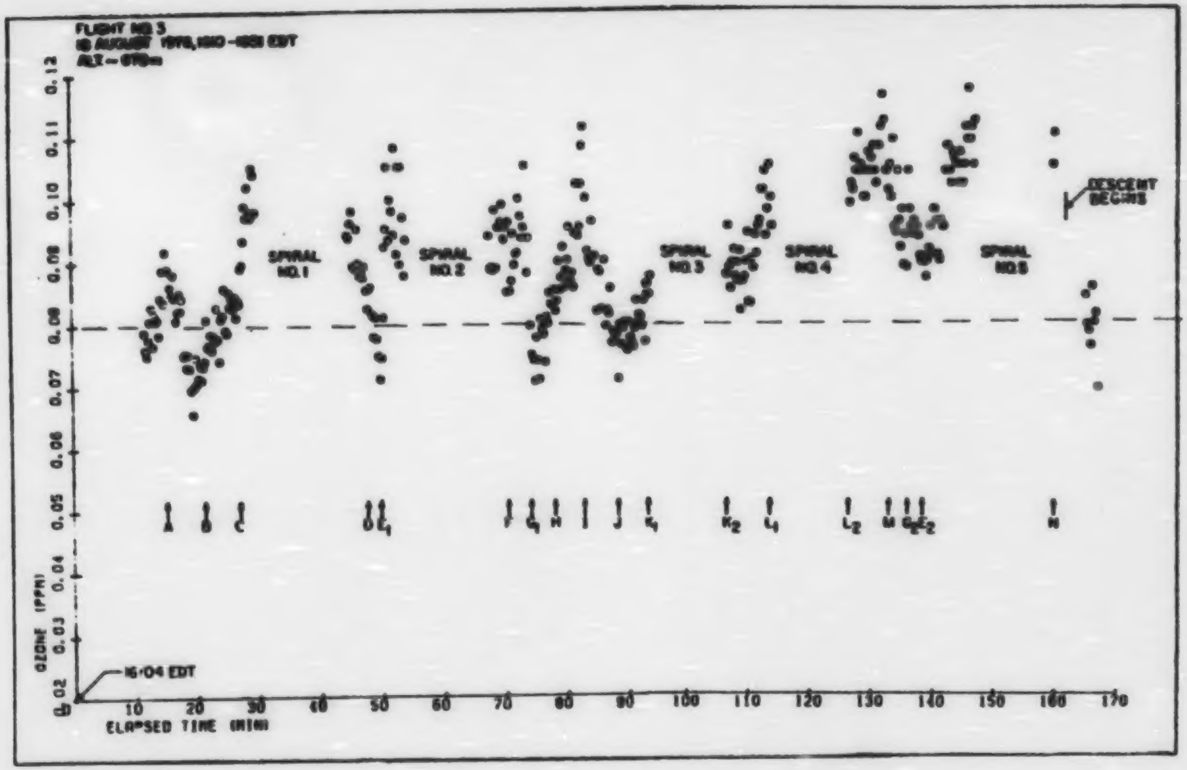

Figure 41. Ozone concentrations during horizontal sampling, Flight No. 3

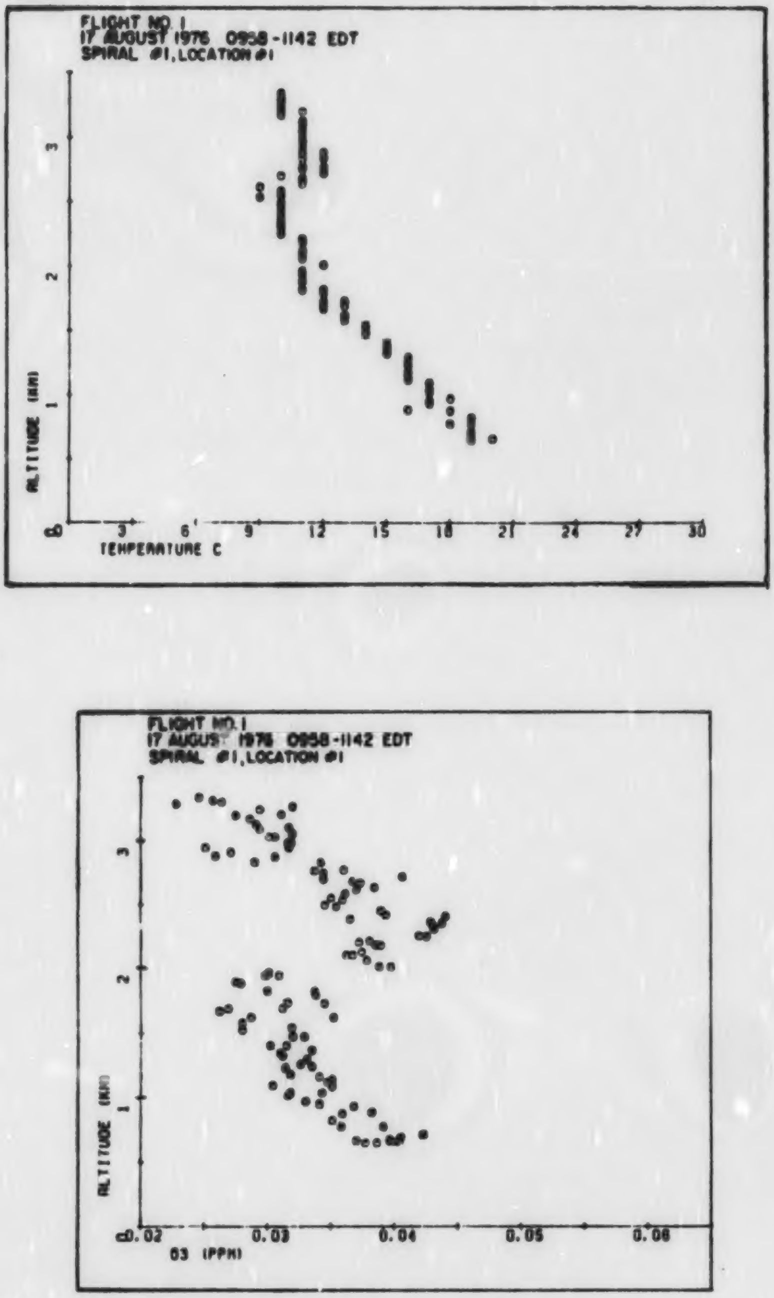

Figure 42. Temperature and ozone profiles, Flight No. 1

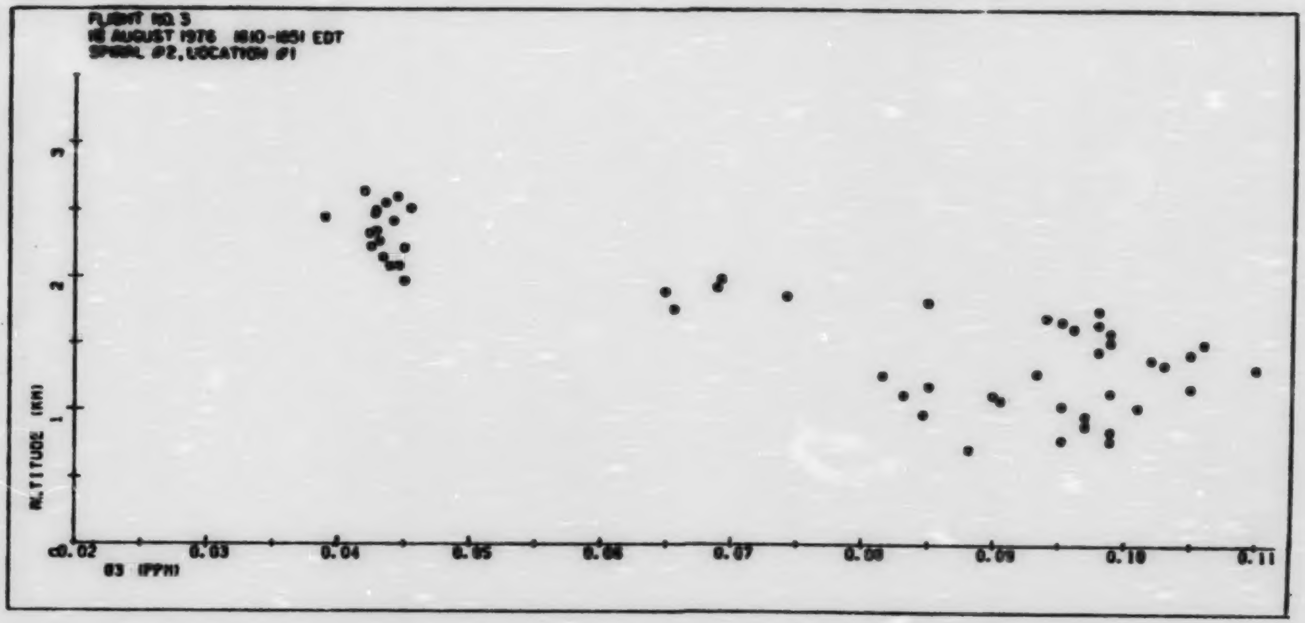

Figure 43. Ozone profile, Flight No. 3

Conditions During the Period of Ozone Buildup

Figures 44, 45, and 46 show the flight tracks and ozone concentrations at selected points for aircraft flights on the 19th, 20th, and 21st, respectively. During this period, surface concentrations increased, reaching peak levels on the 21st, as shown in Figure 29a. On the 19th, morning and afternoon flights were made over the same flight path at an elevation of about 660 meters. During the morning, concentrations along the Philadelphia-Washington corridor averaged about 40 ppb except to the south and east of Washington where the average was about 50 ppb. This increase fits in well with the daily pattern, but may also reflect spatial variations. By the afternoon ozone concentrations at flight altitude had increased substantially, exceeding 100 ppb both to the north-northeast and southwest of Washington. Although Washington's emissions may be contributing to the high ozone concentrations at flight level southwest of the city, they cannot be blamed for the equally high levels to the north-northeast. The ozone field does have considerable structure, as shown in Figure 47, but much of this structure appears to be the result of inputs received by the air mass before reaching the Washington area. Figure 48 shows the vertical distribution of ozone and temperature on the morning of the 19th at a location where the aircraft could descend to low altitudes. Judging from this sounding relatively high concentrations remained throughout the night at a height of 1 kilometer, largely unaffected by the decreases occurring in the surface layer.

The flight tracks and concentrations for the 20th and 21st given in Figures 45 and 46 show much the same patchy ozone structure observed in previous flights. However, in addition, concentrations measured to the southeast and east of Washington and along the Chesapeake Bay are generally lower than those measured somewhat earlier farther inland to the west. Although winds were light during this period, the general drift of air was from east to west. Figure 49 shows the large variations on ozone concentration that were observed while flying northward along the coast on the afternoon of the 21st.

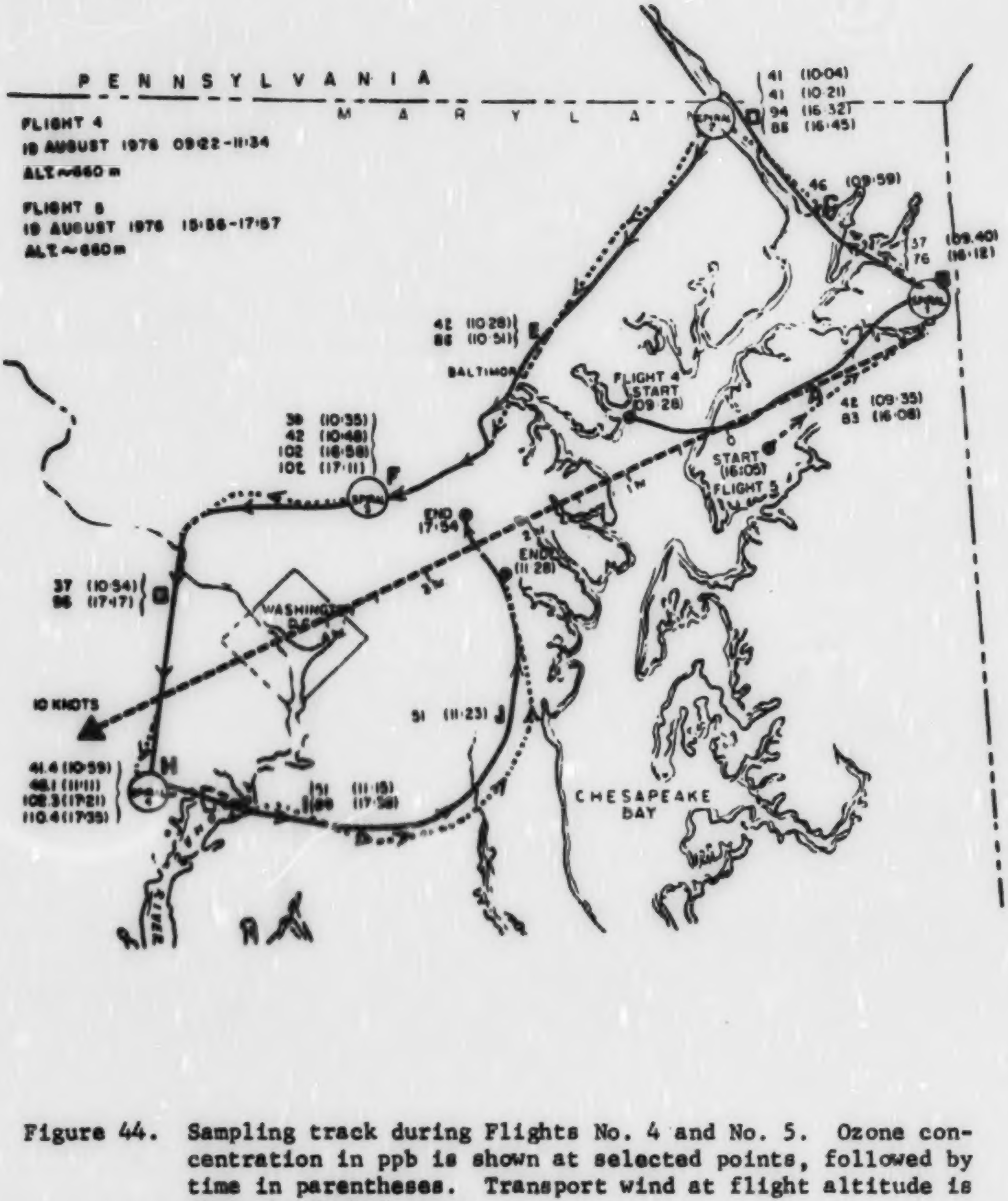
PENNSYLVANIA
MARYLAND
FLIGHT 4
19 AUGUST 1976 09:22-11:34
ALT ~ 660 m
FLIGHT 5
19 AUGUST 1976 15:56-17:57
ALT ~ 660 m
41 (10:04)
41 (10:21)
94 (16:32)
88 (16:45)
D
46 (09:59)
G
37 (09:40)
76 (16:12)
42 (10:28)
88 (10:51)
E
BALTIMORE
FLIGHT 4
START
(09:28)
42 (09:35)
83 (16:08)
A
START
(16:05)
FLIGHT 5
39 (10:35)
42 (10:48)
102 (16:58)
102 (17:11)
F
END
17:54
END
(11:28)
37 (10:54)
96 (17:47)
G
WASHINGTON
D.C.
10 KNOTS
51 (11:23)
J
41.4 (10:59)
46.1 (11:11)
102.3 (17:21)
110.4 (17:35)
H
51 (11:15)
89 (17:58)
I
CHESAPEAKE
BAY
RIVER

Figure 44. Sampling track during Flights No. 4 and No. 5. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

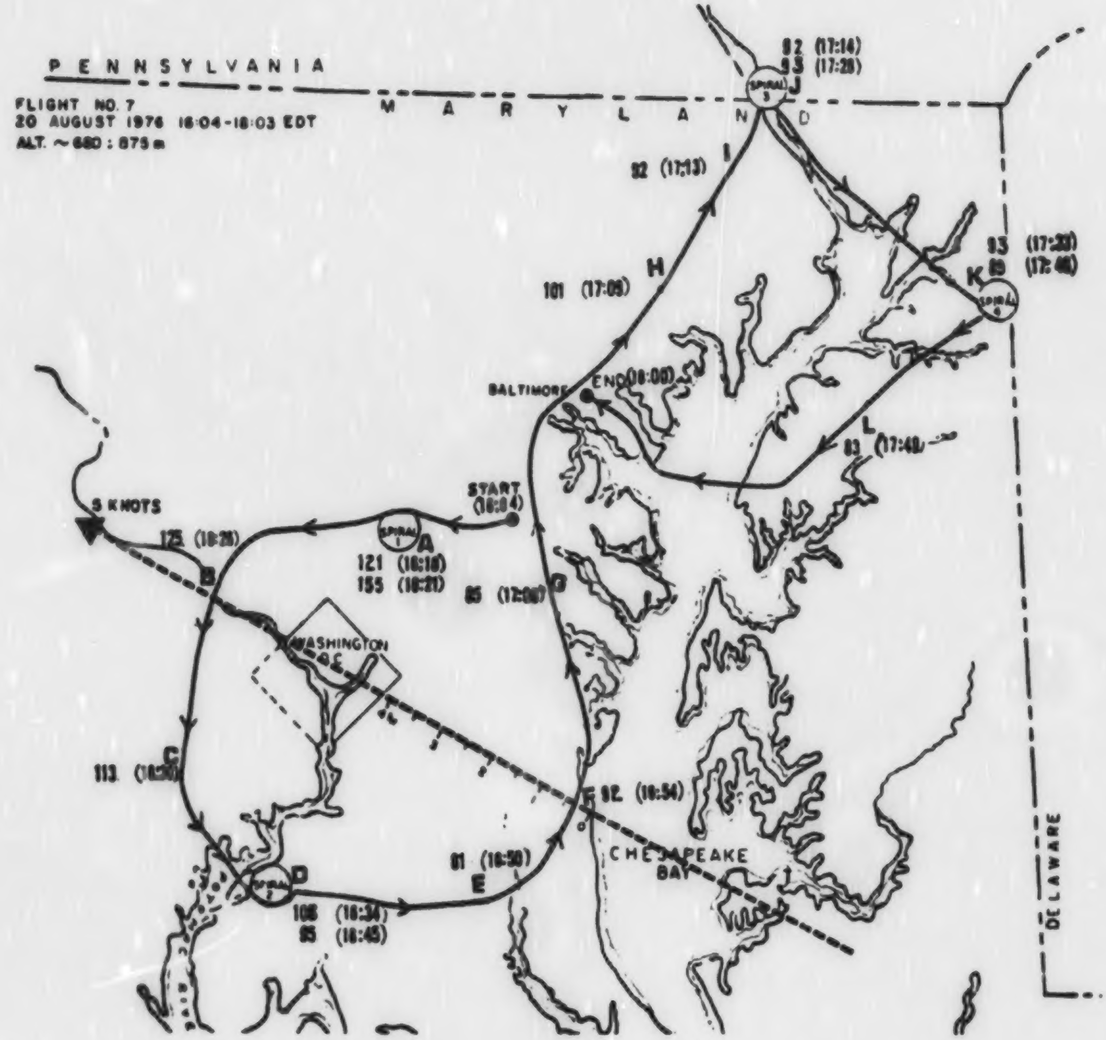
PENNSYLVANIA
MARYLAND
DELAWARE
FLIGHT NO. 7
20 AUGUST 1976 16:04-18:03 EDT
ALT. ~ 680 : 875 m
82 (17:14)
93 (17:28)
SPIRAL 3
J
92 (17:13)
I
101 (17:09)
H
93 (17:20)
89 (17:46)
K
SPIRAL 4
BALTIMORE
END (18:03)
L
83 (17:49)
START (16:04)
SPIRAL 1
A
121 (16:16)
155 (16:21)
5 KNOTS
125 (16:26)
B
85 (17:06)
G
WASHINGTON D.C.
C
113 (16:30)
SPIRAL 2
D
108 (16:34)
85 (16:45)
81 (16:50)
E
F
92 (16:54)
CHESAPEAKE BAY

Figure 45. Sampling track during Flight No. 7. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

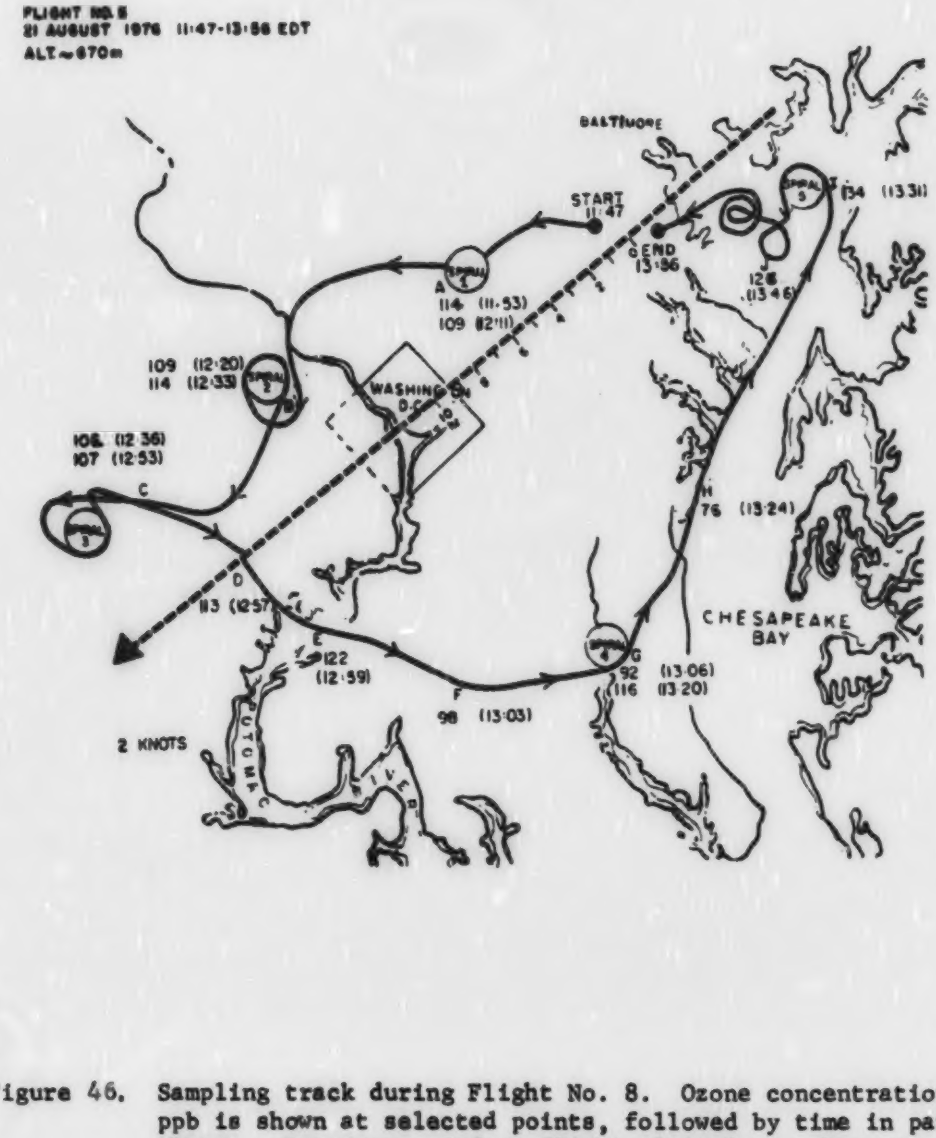
FLIGHT NO. 8
21 AUGUST 1976 11:47-13:56 EDT
ALT.~670m
BALTIMORE
START
11:47
END
13:56
SPIRAL 1
A
114 (11:53)
109 (12:11)
SPIRAL 5
134 (13:31)
126
(13:46)
109 (12:20)
114 (12:33)
SPIRAL 2
B
WASHINGTON
D.C.
10
106 (12:36)
107 (12:53)
C
SPIRAL 3
H
76 (13:24)
D
113 (12:57)
E
122
(12:59)
CHESAPEAKE
BAY
SPIRAL 4
G
92 (13:06)
116 (13:20)
F
98 (13:03)
2 KNOTS
POTOMAC
RIVER

Figure 46. Sampling track during Flight No. 8. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

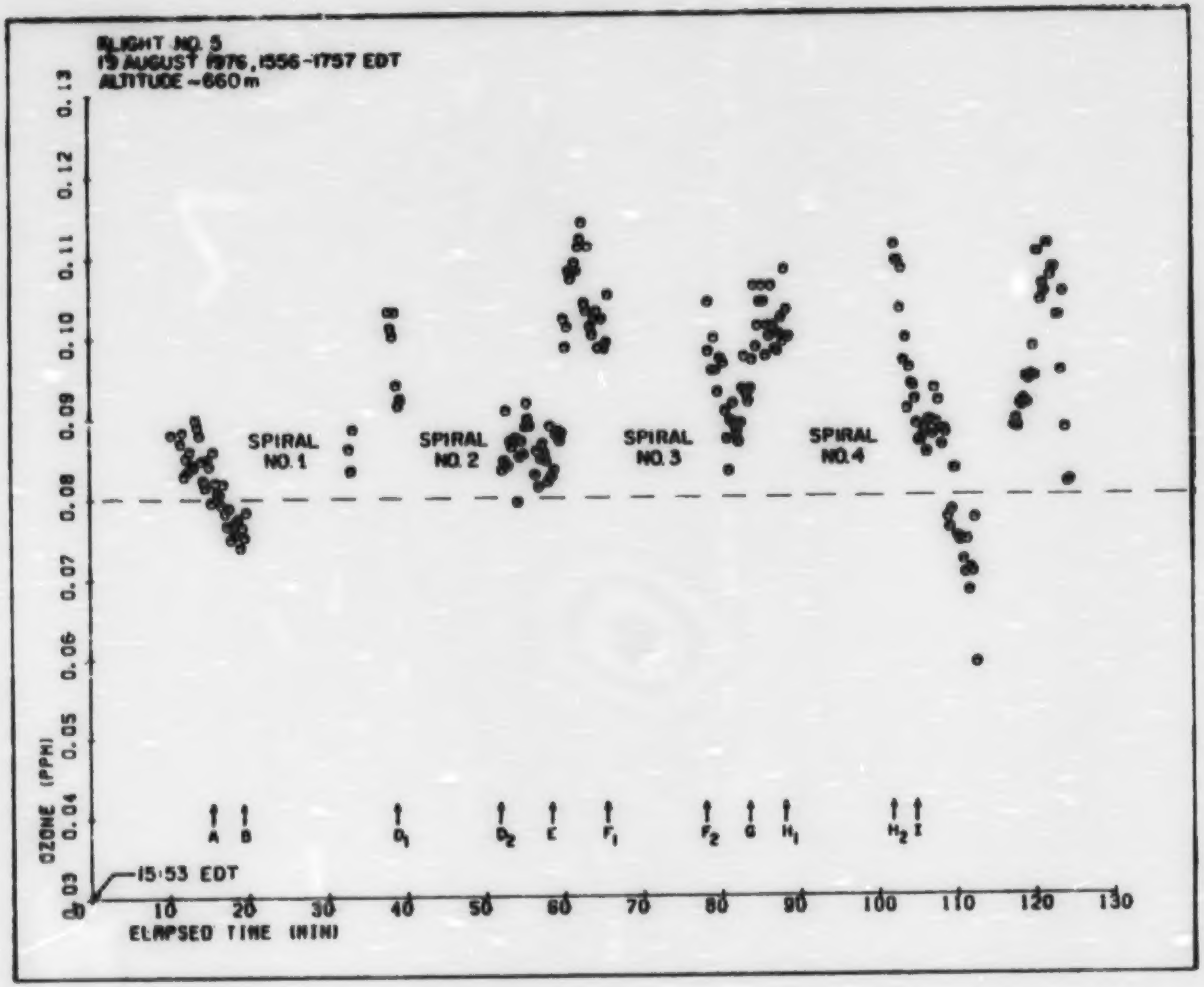

Figure 47. Ozone concentrations during horizontal sampling, Flight No. 5

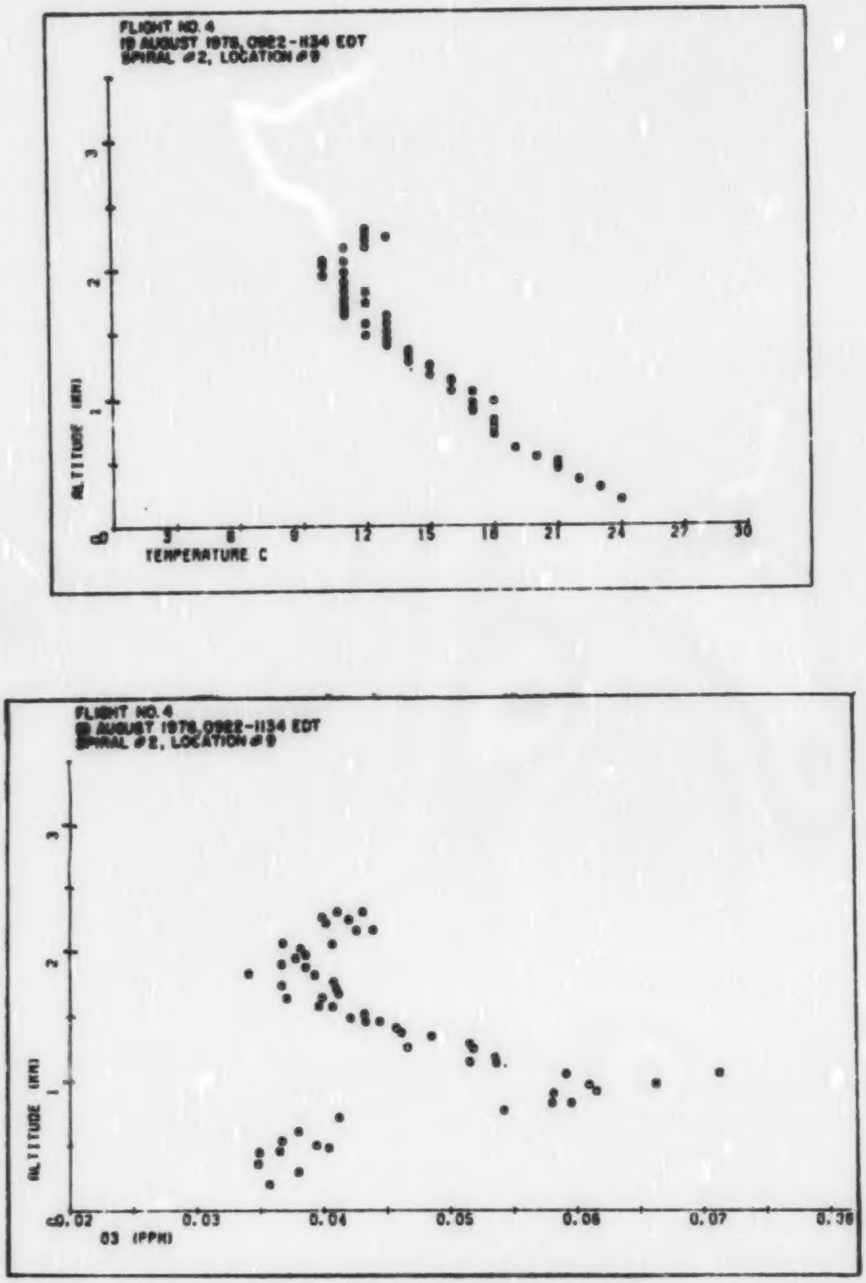

Figure 48. Temperature and ozone profiles, Flight No. 4

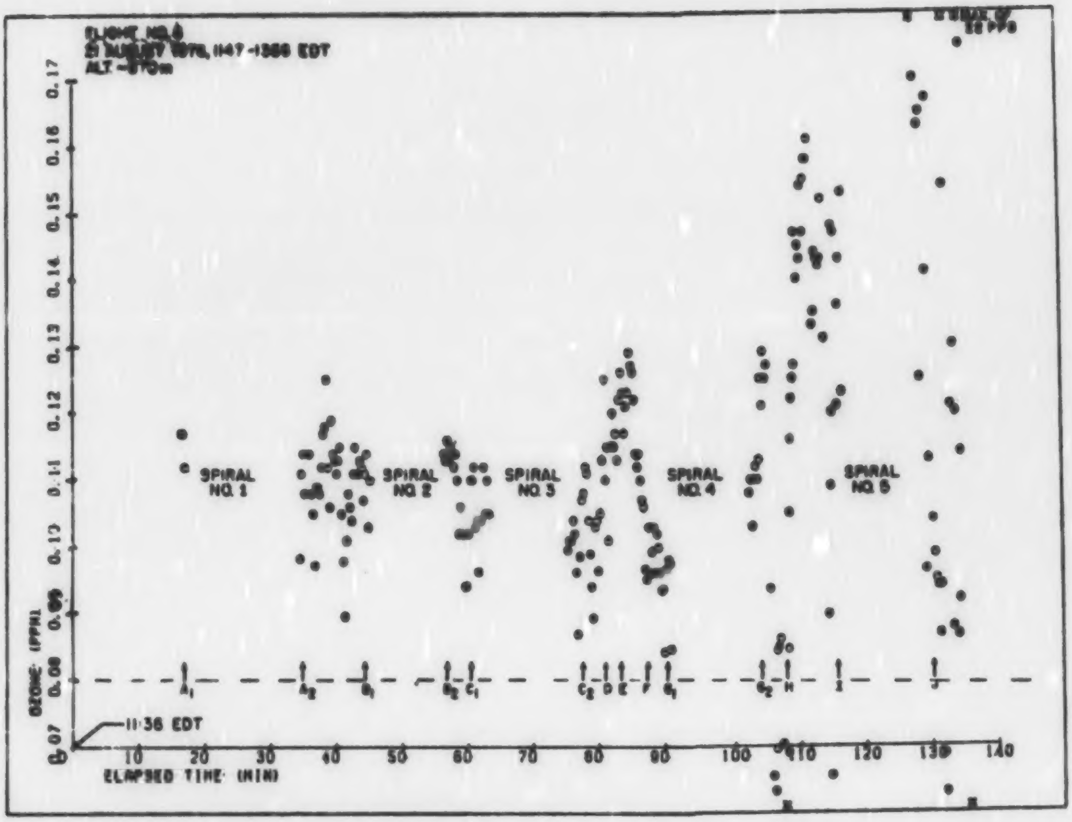

Figure 49. Ozone concentrations during horizontal sampling, Flight No. 8

Summary

During the period of aircraft sampling, ozone levels at a flight altitude of about 670 meters varied significantly about what might be described as the air mass mean. These variations were distributed along the flight path without any obvious relationship to the Washington D.C. emission field. This is not surprising if one places Washington's emission field in perspective with other emissions along the heavily populated and industrialized corridor to the northeast. A sampling program adequate to relate these variations in concentration to emission density maps with confidence would require a better definition of the wind field plus horizontal traverses between ground level and 670 meters.

The buildup of ozone concentrations during the sampling period was associated with a high pressure cell which moved slowly eastward from the Great Lakes, and the development of a strong subsidence inversion over the Washington area. This permitted the accumulation of pollutants and continuing chemical reactions during which even the less reactive organic compounds might play a role.

SECTION VI

SUMMARY OF HYDROCARBON FIELD MEASUREMENTS

This section summarizes the data collected by RTI during the hydrocarbon sampling program, and the results obtained from the detailed analysis program in which 10 percent of the samples were analyzed for hydrocarbon components. Concentrations of nonmethane hydrocarbon (NMHC) and nitrogen oxides are used by local and state agencies to calculate NMHC/NO_x ratios for use in the isopleth method currently being developed for control purposes.[12] Hydrocarbon species data can be used to help identify major contributing sources.

THC, CH_4, NMHC, AND CO DATA

The ambient concentrations of THC, CH_4, NMHC, and CO measured by RTI using a Beckman 6800 Chromatograph and tabulated in their Final Data Report[11] were averaged by site,* sampling period, and day of the week. In addition, averages of the following ratios were calculated for the same data sets: NMHC/THC, NMHC/CO, and THC/CO. Summary tables showing the results of these calculations are provided in Appendix G.

The individual averages tabulated in Appendix G have been regrouped and combined in Table 15. Concentrations and ratios shown in Table 15a were obtained by averaging the values for the four sampling periods. Averages are given for weekdays, for Saturdays, for Sundays, and for all days. Finally, the averages for the six sites were averaged to provide general

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*Sites are identified in Figure 2 of Section II.

Table 15. SUMMARY OF THC, CH_4, NMHC, AND CO DATA FROM SIX RTI SITES — JULY AND AUGUST 1976

(a) Combined average for four sampling periods: 6 to 9 a.m., 9 to 12 a.m., 12 to 3 p.m., 3 to 6 p.m.

Site and identification	Day of week	Average concentration, ppm				Average ratio		
		THC	CH_4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
CAMP (16)	Weekdays	2.18	2.02	0.61	2.79	0.26	0.25	1.00
	Saturday	2.00	1.58	0.42	1.71	0.20	0.36	1.60
	Sunday	1.86	1.52	0.33	1.10	0.15	0.38	2.40
	All days	2.12	1.57	0.55	2.42	0.24	0.28	1.28
WEST END (15)	Weekdays	2.53	1.56	0.97	2.37	0.37	0.49	1.31
	Saturday	2.90	1.74	1.16	1.89	0.37	0.64	1.60
	Sunday	2.48	1.58	0.90	1.04	0.35	0.88	2.46
	All days	2.56	1.58	0.98	2.19	0.36	0.55	1.46
ALEXANDRIA (4)	Weekdays	2.45	1.58	0.87	1.65	0.33	0.65	1.87
	Saturday	2.55	1.64	0.90	1.32	0.34	1.16	2.93
	Sunday	2.36	1.59	0.82	1.12	0.34	1.14	2.98
	All days	2.46	1.59	0.87	1.54	0.34	0.77	2.15
FAIRFAX (2)	Weekdays	1.90	1.58	0.33	0.80	0.15	0.56	3.68
	Saturday	1.81	1.58	0.24	0.56	0.12	1.28	6.35
	Sunday	1.84	1.57	0.27	0.52	0.12	1.08	7.30
	All days	1.88	1.57	0.30	0.72	0.14	0.74	4.58
SUITLAND (12)	Weekdays	2.01	1.62	0.38	0.96	0.18	0.54	3.14
	Saturday	2.14	1.68	0.46	0.94	0.19	1.08	4.37
	Sunday	2.08	1.62	0.45	0.76	0.19	0.78	3.92
	All days	2.04	1.63	0.41	0.92	0.18	0.66	3.46
BETHESDA (9)	Weekdays	1.78	1.55	0.23	0.90	0.11	0.42	2.90
	Saturday	1.80	1.58	0.22	0.85	0.10	0.86	4.71
	Sunday	1.78	1.56	0.23	0.72	0.10	0.98	4.64
	All days	1.78	1.55	0.22	0.88	0.11	0.53	3.32
All sites	Weekdays	2.14	1.65	0.56	1.58	0.23	0.48	2.32
	Saturday	2.20	1.63	0.57	1.21	0.22	0.90	3.76
	Sunday	2.07	1.57	0.50	0.88	0.21	0.87	3.95
	All days	2.14	1.58	0.56	1.44	0.23	0.59	2.71

Table 15 (continued). SUMMARY OF THC, CH_4, NMHC, AND CO DATA FROM SIX RTI SITES — JULY AND AUGUST 1976

(b) Average for 6 to 9 a.m. period only

Site and identification	Day of week	Average concentration, ppm				Average ratio		
		THC	CH_4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
CAMP (16)	Weekdays	2.33	1.65	0.67	3.00	0.27	0.24	0.96
	Saturday	2.07	1.59	0.49	1.87	0.23	0.36	1.55
	Sunday	1.96	1.71	0.24	1.31	0.11	0.19	2.00
	All days	2.25	1.65	0.59	2.64	0.25	0.25	1.17
WEST END (15)	Weekdays	2.70	1.63	1.07	3.07	0.38	0.42	1.08
	Saturday	2.93	1.90	1.03	2.13	0.35	0.48	1.39
	Sunday	2.80	1.67	1.13	1.07	0.38	1.03	2.66
	All days	2.73	1.66	1.07	2.78	0.38	0.49	1.27
ALEXANDRIA (4)	Weekdays	2.71	1.65	1.06	2.22	0.36	0.57	1.52
	Saturday	2.45	1.75	0.70	1.75	0.27	0.86	2.32
	Sunday	2.50	1.75	0.75	1.20	0.29	0.78	2.58
	All days	2.65	1.67	0.97	2.03	0.34	0.63	1.75
FAIRFAX (2)	Weekdays	2.01	1.61	0.40	1.01	0.17	0.39	2.57
	Saturday	1.86	1.65	0.21	0.65	0.10	1.06	5.89
	Sunday	2.15	1.65	0.50	0.65	0.19	1.18	6.61
	All days	2.01	1.62	0.39	0.90	0.16	0.61	3.68
SUITLAND (12)	Weekdays	2.15	1.68	0.46	1.34	0.20	0.41	1.96
	Saturday	2.30	1.99	0.31	1.39	0.14	0.39	2.51
	Sunday	2.26	1.66	0.60	0.78	0.24	1.54	5.44
	All days	2.19	1.72	0.47	1.25	0.20	0.61	2.65
BETHESDA (9)	Weekdays	1.92	1.64	0.28	1.08	0.13	0.33	2.17
	Saturday	2.04	1.73	0.31	0.93	0.14	1.45	5.97
	Sunday	2.10	1.70	0.40	1.02	0.17	1.01	4.14
	All days	1.95	1.66	0.30	1.06	0.14	0.56	2.91
All sites	Weekdays	2.30	1.64	0.66	1.95	0.25	0.39	1.71
	Saturday	2.28	1.77	0.51	1.45	0.20	0.77	3.27
	Sunday	2.30	1.69	0.60	1.00	0.23	0.96	3.90
	All days	2.30	1.66	0.63	1.78	0.24	0.52	2.24

estimates for the entire area. These areawide estimates show relatively small differences between weekday and weekend concentrations of hydrocarbons, including the nonmethane hydrocarbons, but, as would be expected, large differences in the weekday and weekend concentrations of carbon monoxide. Observed HC concentrations agree roughly with the THC emission density maps presented in Section III, with the highest average concentrations of both THC and NMHC being found at the West End Library and Alexandria sites, followed by the CAMP site. On the average, nonmethane hydrocarbons made up about 20 to 25 percent of the total hydrocarbons, but the differences among the sites are large, ranging from 11 percent at Bethesda to 36 percent at the West End Library. The largest weekday-weekend differences in NMHC among the sites occurred at the CAMP station, where by Sunday the average concentration had dropped to approximately one-half of its weekday value. Because of its location in a commercial area removed from major shopping centers, the progressive decrease in concentration from weekday to Saturday to Sunday at this site would be expected.

Table 15b is organized in the identical fashion as Table 15a, but the tabulated values are for the 0600 to 0900 a.m. period. The details of the two tables differ, but the general conclusions to be drawn are much the same. Again, the biggest weekend drop in NMHC occurs at the CAMP station. Although the "all site" average NMHC concentration is lower on Sundays than on weekdays, the Sunday concentration is actually higher than the weekday concentration at four of the six sites, apparently reflecting more complicated weekly emission cycles, particularly during the 0600 to 0900 a.m. period.

Figure 50 shows the relative changes in average concentration of carbon monoxide and nonmethane hydrocarbons which occurred during the four sampling periods of the day. Although there are pronounced differences among sites and seemingly erratic behavior in many of the nonmethane hydrocarbon curves for Saturday and Sunday when the number of observations and the concentration levels were low, the combined site curves for

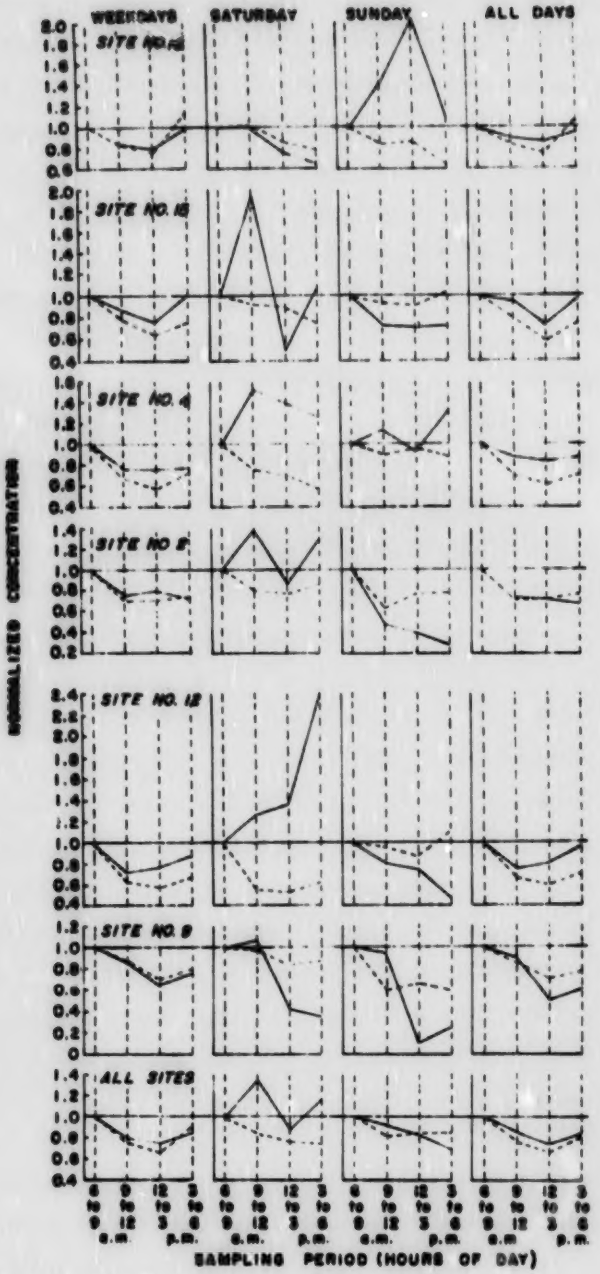


Figure 50. July and August 1976 average NMHC concentrations (solid lines) and average CO concentrations (dashed lines) normalized to 6 to 9 a.m. values

weekdays and all days are quite regular. These curves show the typical midday decrease in concentration that results from improved atmospheric mixing, the decrease in emissions that results from a reduction in traffic during that part of the day, and photochemical reactions. Also, the diurnal change in carbon monoxide concentration is greater than that in nonmethane hydrocarbons, presumably reflecting a more complete dependence on emissions from vehicular sources.

NMHC/NO_x RATIOS

Tables 16 and 17 list average NMHC concentrations obtained from the RTI Beckman 6800 data, NO_x concentrations reported by the local agencies, and the NMHC/NO_x ratios calculated from these averages for the CAMP and Fairfax sites. This information is provided for Sundays, weekdays, and Saturdays, and for all days, for each of the four sampling periods. The same information is provided for the Bethesda and Suitland sites in Table 18 except that no breakdown by day-of-the-week is given because of the small number of days with both NMHC and NO_x data.

The isopleth technique proposed by Dimitriades[12] for oxidant control strategy development uses an average 0600 to 0900 a.m. NMHC/NO_x ratio. Calculating a weighted average of the 0600 to 0900 a.m. ratios from the four sites gives an overall, areawide estimate for this ratio of 9.7. A better estimate for the Washington CBD is probably obtained by omitting the Fairfax data; this procedure gives a weighted average of 6.7.

HC SPECIES DATA

Table 19 shows the periods during the July/August RTI sampling program for which detailed hydrocarbon data were obtained. For most of these periods, concentrations of THC, CH_4, NMHC, and CO are also available from the regular analysis. Because the concentrations of precursors during the early morning are of particular importance, most of the observations

Table 16. NMHC AND NO_x AVERAGE CONCENTRATIONS AND CORRESPONDING RATIOS AT THE CAMP STATION

Sampling period, EDT	Parameter	Average			
		Sunday	Weekdays	Saturday	All days
0600-0900	NMHC conc. (ppm)	0.28	0.70	0.47	0.62
	NO_x conc. (ppm)	0.035	0.101	0.046	0.086
	$\overline{NMHC}/\overline{NO_x}$	8.0	6.9	10.2	7.2
	Number of cases	5	32	6	43
0900-1200	NMHC conc. (ppm)	0.40	0.59	0.40	0.54
	NO_x conc. (ppm)	0.032	0.075	0.044	0.065
	$\overline{NMHC}/\overline{NO_x}$	12.5	7.9	9.1	8.3
	Number of cases	6	31	6	42
1200-1500	NMHC conc. (ppm)	0.64	0.60	0.30	0.57
	NO_x conc. (ppm)	0.034	0.048	0.034	0.045
	$\overline{NMHC}/\overline{NO_x}$	18.8	12.5	8.8	12.7
	Number of cases	5	30	4	39
1500-1800	NMHC conc. (ppm)	0.30	0.70	0.40	0.62
	NO_x conc. (ppm)	0.028	0.068	0.030	0.058
	$\overline{NMHC}/\overline{NO_x}$	10.7	10.3	13.3	10.7
	Number of cases	5	32	5	42

Table 17. NMHC AND NO_x AVERAGE CONCENTRATIONS AND CORRESPONDING RATIOS AT FAIRFAX

Sampling period, EDT	Parameter	Average			
		Sunday	Weekdays	Saturday	All days
0600-0900	NMHC conc. (ppm)	0.50	0.41	0.21	0.39
	NO_x conc. (ppm)	0.016	0.033	0.033	0.030
	$\overline{NMHC}/\overline{NO_x}$	31.2	12.4	6.4	13.1
	Number of cases	8	35	8	51
0900-1200	NMHC conc. (ppm)	0.24	0.30	0.29	0.29
	NO_x conc. (ppm)	0.015	0.022	0.021	0.021
	$\overline{NMHC}/\overline{NO_x}$	16.0	13.6	13.8	14.0
	Number of cases	7	34	8	49
1200-1500	NMHC conc. (ppm)	0.20	0.31	0.18	0.27
	NO_x conc. (ppm)	0.012	0.016	0.014	0.015
	$\overline{NMHC}/\overline{NO_x}$	16.7	19.4	12.9	17.9
	Number of cases	7	30	6	43
1500-1800	NMHC conc. (ppm)	0.14	0.32	0.27	0.28
	NO_x conc. (ppm)	0.012	0.019	0.014	0.017
	$\overline{NMHC}/\overline{NO_x}$	11.7	16.8	19.3	16.4
	Number of cases	7	30	6	43

Table 18. NMHC AND NO_x AVERAGE CONCENTRATIONS AND CORRESPONDING RATIOS AT BETHESDA AND SUITLAND

Sampling period, EDT	Parameter	Average, all days	
		Bethesda	Suitland
0600-0900	NMHC conc. (ppm)	0.25	0.55
	NO_x conc. (ppm)	0.035	0.118
	$\overline{NMHC}/\overline{NO_x}$	7.1	4.7
	Number of cases	6	11
0900-1200	NMHC conc. (ppm)	0.31	0.41
	NO_x conc. (ppm)	0.032	0.044
	$\overline{NMHC}/\overline{NO_x}$	9.7	9.3
	Number of cases	10	16
1200-1500	NMHC conc. (ppm)	0.22	0.52
	NO_x conc. (ppm)	0.028	0.014
	$\overline{NMHC}/\overline{NO_x}$	7.9	37.1
	Number of cases	12	16
1500-1800	NMHC conc. (ppm)	0.16	0.53
	NO_x conc. (ppm)	0.038	0.035
	$\overline{NMHC}/\overline{NO_x}$	4.2	15.1
	Number of cases	17	26

Table 19. PERIODS WITH DETAILED HYDROCARBON ANALYSES AT SIX SITES

		Fairfax				Bethesda				Alexandria				Suitland				CAMP				West End			
Month	Day	6-9	9-12	12-15	15-18	6-9	9-12	12-15	15-18	6-9	9-12	12-15	15-18	6-9	9-12	12-15	15-18	6-9	9-12	12-15	15-18	6-9	9-12	12-15	15-18
July	10									X															
	11									X															
	12									X								X							
	13									X								X^*							
	14									X^*								X							
	15									X								X							
	16									X^*								X							
	17									X								X							
	18			X^*	X^*			X^*	X^*	X	X^*	X^*	X^*		X	X	X	X	X						
	19	X^*	X^*	X^*	X^*	X^*	X^*	X^*	X^*	X^*				X^*				X		X^*					
	20	X^*																X							
	21																								
	22					X												X							
	23																								
	24	X																X							
	25																								
	26	X																X							X
	27																								
	28	X^*																X							
	29																								
	30																								
	31																								
Aug.	1																								
	2																								
	3																								
	4					X																			
	5	X			X				X				X					X	X	X	X				
	6	X^*	X^*	X^*	X	X	X						X						X	X	X				
	7																								
	8	X																							
	9																								
	10	X																X							
	11	X				X												X							
	12	X																X							
	13				X		X	X																	
	14	X	X		X^*	X		X	X										X	X	X				
	15	X^*	X^*			X^*																			
	16																								
	17																								
	18	X	X	X		X				X								X	X	X		X			
	19																								
	20																	X							
	21	X	X	X		X													X	X					
	22	X	X	X	X	X													X	X	X				
	23	X																X							
	24	X								X								X				X			
	25	X	X		X		X	X										X		X					
	26	X	X	X	X		X	X	X									X	X	X	X				
	27	X	X				X											X	X						
	28	X	X			X^*	X^*											X	X						
	29	X	X															X							
	30	X	X																X						
	31		X																X						

Note: X indicates both detailed and routine data available.
X^* indicates detailed data only.

were taken over the 0600 to 0900 a.m. period. Of the 76 samples analyzed from this time period, 50 were collected at the CAMP and Fairfax sites, 23 at the Bethesda and Alexandria sites, and the remaining 3 at the West End Library and Suitland sites. The results from this 0600 to 0900 a.m. period are summarized in Tables 20 through 24 and in Figure 51. Table 20 presents the average and standard deviation of concentrations determined from the detailed analyses (below) and the same information determined from the corresponding routine analyses (above) to the extent that it was available. As can be seen from the standard deviations, the range of concentrations measured in most cases is very large. Average concentrations of the 11 hydrocarbon components, plus that of nonmethane hydrocarbons, have been taken from Table 20 and ordered roughly by magnitude to obtain the listing in Table 21. With a few exceptions, the component concentrations decrease in the order shown in the table at all four sites. Concentrations are similar at the Alexandria and CAMP sites with the principal exceptions of the ethylene/ethane and toluene components. Taken together, these species make up much of the difference in NMHC measured at the two sites. This suggests an impact on the Alexandria site of very local sources of these hydrocarbons. Inspection of the data shows 3 days (July 16th, July 18th, and August 24th) with exceptionally high concentrations of ethylene/ethane during the 0600 to 0900 a.m. sampling period, but as of now these high values have not been accounted for. Concentrations are also quite similar at the subruban sites in Fairfax and Bethesda and are typically less than half those at the center city CAMP and Alexandria sites.

Lonneman, et al.[13,14] offer a technique for estimating the total nonmethane HC concentration due to vehicular tailpipe emissions from measured acetylene (C_2H_2) concentrations. In his most recent paper,[14] Lonneman uses 15.5 as the $NMHC/C_2H_2$ ratio for this purpose. Multiplying this factor by the average acetylene concentration in parts per billion carbon at each monitoring site gives estimates which when compared with measured concentrations indicate that vehicular emissions contribute approximately

Table 20. AVERAGE CONCENTRATIONS OF HYDROCARBONS AND CARBON MONOXIDE AT FOUR MONITORING SITES (0600-0900 EDT)

Component	CAMP			Alex. Health Dept.			Fairfax			Bethesda		
	N	Mean, ppmc	σ	N	Mean, ppmc	σ	N	Mean, ppmc	σ	N	Mean, ppmc	σ
Carbon monoxide	24	2.61	1.28	9	1.89	1.18	19	0.76	0.45	8	1.08	0.56
Total hydrocarbons	24	2.31	0.55	9	2.74	0.47	19	1.81	0.20	8	1.86	0.28
Methane	24	1.65	0.21	9	1.82	0.46	19	1.63	0.12	8	1.64	0.17
Nonmethane hydrocarbons	24	0.67	0.45	9	0.92	0.62	19	0.18	0.20	8	0.22	0.24
		(ppbv)			(ppbv)			(ppbv)			(ppbv)	
Ethylene/ethane	26	55.0	49.6	12	225.	271.	24	52.6	38.3	11	39.8	21.6
Propane	26	4.84	4.21	12	4.72	2.42	24	2.51	1.22	11	2.00	0.91
Propylene	26	4.37	2.88	12	4.63	1.91	24	2.07	1.30	11	1.81	1.41
Acetylene	26	16.7	7.44	12	16.8	8.06	24	5.64	4.24	11	6.50	4.53
N-butane	26	17.8	7.20	12	16.0	6.58	24	7.63	5.08	11	6.73	3.24
1-butene	26	0.92	0.51	12	1.06	0.55	24	0.30	0.27	11	0.28	0.23
Isobutane	26	5.09	2.11	12	4.92	2.57	24	2.10	1.55	11	1.92	1.02
Isopentane	26	18.6	9.19	12	15.9	7.55	24	6.95	4.60	11	6.65	4.25
Cyclopentane	26	0.45	0.52	12	0.22	0.39	24	0.08	0.19	11	0.06	0.21
N-pentane	26	5.48	2.61	12	5.95	4.73	24	2.87	1.92	11	2.66	1.66
Toluene	26	15.4	14.1	12	27.3	57.7	22	16.9	27.0	11	15.6	14.7

Note: N = number of samples; σ = standard deviation of observations.

Table 21. CONCENTRATIONS OF HYDROCARBONS AT FOUR MONITORING SITES ORDERED BY MAGNITUDE (0600-0900 EDT)

Component	Concentrations, ppbv			
	Alex. Health Dept.	CAMP	Fairfax	Bethesda
Nonmethane hydrocarbons[a]	920	670	180	220
Ethylene/ethane	225	55.0	52.6	39.8
Toluene	27.3	15.4	16.9	15.6
N-butane	16.0	17.8	7.63	6.73
Isopentane	15.9	18.6	6.95	6.65
Acetylene	16.8	16.7	5.64	6.50
N-pentane	5.95	5.48	2.87	2.66
Isobutane	4.92	5.09	2.10	1.92
Propane	4.72	4.84	2.51	2.00
Propylene	4.63	4.37	2.07	1.81
1-butene	1.06	0.92	0.30	0.28
Cyclopentane	0.22	0.45	0.08	0.06
Estimated NMHC from vehicular sources (after Lonneman[14])	520	518	175	202

[a] Data reported by RTI in terms of ppbc.

Table 22. COMPARISON OF AVERAGE HYDROCARBON TO ACETYLENE RATIOS WITH RATIOS OBTAINED IN TUNNEL AIR

Component	Fairfax	Bethesda	Alex. Health Dept.	CAMP	Tunnel air[a]
Ethylene/ ethane	9.3	6.1	13.4	3.3	–
Toluene	10.5	8.4	5.7	3.2	1.27
N-butane	2.7	2.1	1.9	2.1	0.97
Isopentane	3.1	2.6	2.4	2.8	1.25
N-pentane	1.3	1.0	0.88	0.82	0.62
Isobutane	0.74	0.59	0.59	0.61	0.34
Propane	0.67	0.46	0.42	0.44	–
Propylene	0.56	0.42	0.42	0.39	0.61
1-butene	0.10	0.08	0.12	0.12	0.34[b]
Cyclopentane	0.03	0.02	0.03	0.07	0.76[c]

[a] From Lonneman[13]

[b] Represents sum of 1-butene and isobutylene

[c] Represents sum of cyclopentane and 2 methylpentane

Table 23. COMMON SOURCES OF HYDROCARBONS

Hydrocarbon	Symbol	Category	Sources	
			Primary	Secondary
Ethane	$C_2 H_6$	Paraffin	Natural gas and petroleum	Automobile exhaust
Ethylene	$C_2 H_4$	Olefin	Automobile exhaust	Synthetic plastic industry
Acetylene	$C_2 H_2$	Acetylene	Automobile exhsust	Acetylene Prod. and industrial usage
Propane	$C_3 H_8$	Paraffin	Industrial usage, petrochemical processes, natural gas, oil field losses	
Propylene (Propene)	$C_3 H_6$	Olefin	Automobile exhaust	Gasoline evaporation, chemical processes
Iso-butane	$C_4 H_{10}$	Paraffin	Heating, city and industrial gas manufacturing fuel evaporation	
n-Butane	$C_4 H_{10}$	Paraffin	Fuel evaporation and automobile exhaust	
1-Butene	$C_4 H_8$	Olefin	Automobile exhaust, gasoline evaporation, raw material for synthetic rubber	
Iso-pentane (2-methylbutane)	$C_5 H_{12}$	Paraffin	Automobile exhaust, gasoline evaporation	
Cyclopentane	$C_5 H_{10}$	Paraffin	Automobile exhaust, gasoline evaporation	
n-Pentane	$C_5 H_{12}$	Paraffin	Automobile exhaust, gasoline evaporation	
Toluene	$C_7 H_8$	Aromatic	Petroleum and coal tars	Automobile fuel and exhaust[a] and solvent
o-Xylene	$C_8 H_{10}$	Aromatic	Petroleum and coal tars	Fuel evaporation[a] solvents

[a] An increase in concentrations of aromatic can be expected as lead in fuel is phased out.[6]

Table 24. LINEAR CORRELATION COEFFICIENTS BETWEEN CARBON MONOXIDE AND ACETYLENE AND VARIOUS HYDROCARBONS AT FOUR MONITORING SITES (0600–0900 EDT)

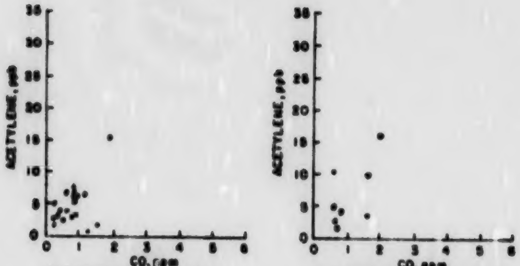
(a) Carbon monoxide versus hydrocarbons

Site		THC	Methane	NMHC	Carbon monoxide	Ethylene/ ethane	Propane	Pro- pylene	Acet- ylene	N- butane	1- butene	Iso- butane	Iso- pentane	Cyclo- pentane	N- pentane	Toluene
CAMP	r	0.72*	0.48*	0.63*	1.00*	0.34	0.00	0.73*	0.69*	0.74*	0.81*	0.70*	0.77*	0.40	0.70*	0.11
	n	54	54	54	54	24	24	24	24	24	24	24	24	24	24	24
Alex. Health Dept.	r	0.44*	0.59*	0.26	1.00*	-0.36	0.70*	0.95*	0.69*	0.82*	0.55	0.77*	0.78*	-0.31	0.70*	0.77*
	n	48	48	48	48	9	9	9	9	9	9	9	9	9	9	9
Fairfax	r	0.67*	0.54*	0.51*	1.00*	0.14	0.43	0.46*	0.51*	0.67*	0.51*	0.65*	0.64*	0.35	0.56*	0.29
	n	53	53	53	53	19	19	19	19	19	19	19	19	19	19	17
Bethesda	r	0.57*	0.81*	0.14	1.00*	-0.61	0.61	-0.04	0.62	0.71	0.57	0.61	0.67	-0.27	0.63	-0.20
	n	52	52	52	52	8	8	8	8	8	8	8	8	8	8	8

(b) Acetylene versus other hydrocarbons and carbon monoxide

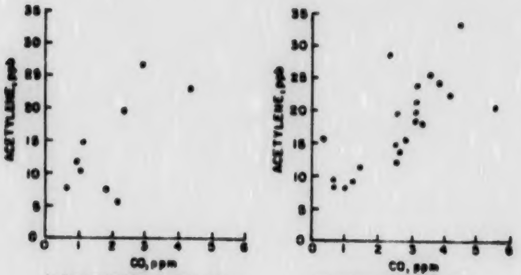
Site		THC	Methane	NMHC	Carbon monoxide	Ethylene/ ethane	Propane	Pro- pylene	Acet- ylene	N- butane	1- butene	Iso- butane	Iso- pentane	Cyclo- pentane	N- pentane	Toluene
CAMP	r	0.49*	0.50*	0.36	0.69*	0.51*	0.16	0.73*	1.00*	0.70*	0.63*	0.72*	0.70*	0.46*	0.55*	0.02
	n	24	24	24	24	26	26	26	26	26	26	26	26	26	26	26
Alex. Health Dept.	r	-0.07	0.39	-0.34	0.69*	-0.09	0.49	0.73*	1.00*	0.73*	0.40	0.85*	0.86*	0.32	0.47	0.25
	n	9	9	9	9	12	12	12	12	12	12	12	12	12	12	12
Fairfax	r	0.69*	-0.04	0.70*	0.51*	0.38	0.38	0.85*	1.00*	0.74*	0.65*	0.70*	0.79*	-0.14	0.32	0.28
	n	19	19	19	19	24	24	24	24	24	24	24	24	24	24	22
Bethesda	r	0.69	0.19	0.66	0.62	0.08	0.94*	0.50	1.00*	0.89*	0.66*	0.90*	0.94*	-0.34	0.86*	0.41
	n	8	8	8	8	11	11	11	11	11	11	11	11	11	11	11

* Indicates significance at 5 percent level.



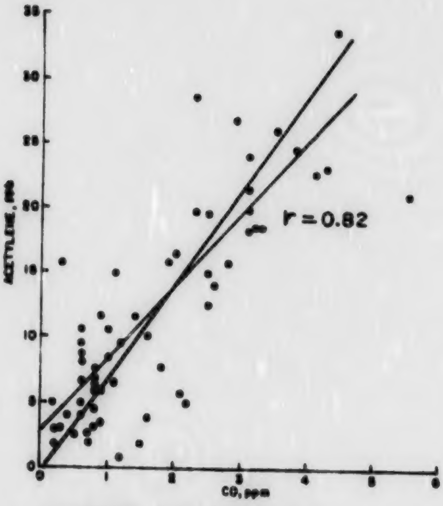
(a) FAIRFAX, GCA NO. 2

(b) BETHSEDA, GCA NO. 9



(c) ALEXANDRIA, GCA NO. 4

(d) CAMP, GCA NO. 18



(e) COMBINED DATA (SITES 2,4,9,18)

Figure 51. Relationship between acetylene and carbon monoxide concentrations at four sites (0600 to 0900 EDT)

56, 77, 97, and 92 percent of the nonmethane hydrocarbons at the Alexandria, CAMP, Fairfax and Bethesda sites, respectively. Because of possible uncertainties in the total NMHC estimates as measured by the FID instrument,[15] comparisons of vehicular NMHC to total NMHC should be made with caution. However, if one accepts the relationship between hydrocarbon/acetylene ratios and the contribution of vehicular emissions to NMHC concentrations assumed by Lonneman, it is clear that the contribution from vehicles is approximately 3 times as great at the CAMP and Alexandria sites as at the outlying sites of Fairfax and Bethesda. It also appears that while other sources contribute significantly to NMHC concentrations at the CAMP site, and to a great extent in Alexandria, vehicular emissions are responsible for nearly all of the nonmethane hydrocarbons in Bethesda and Fairfax.

Lonneman, et al.[13] have also presented ratios, calculated from concentrations expressed in parts per billion carbon, of the concentration of a number of hydrocarbon species to that of acetylene in tunnel air. When ratios determined from ambient urban air samples are significantly greater than these tunnel ratios, it suggests the presence of other NMHC sources. Table 22 lists such hydrocarbon/acetylene ratios determined from the average concentrations of the species listed in Table 21 after conversion to parts per billion carbon. Tunnel ratios for eight of these species, taken from Lonneman, are also included in the table for comparison. Table 23, from an unpublished paper by Sennett,[16] shows the type of source information that is available for use with these ratios in identifying source classes.

Some of the conclusions to be drawn from Table 22 with regard to vehicular NMHC contributions do not appear to agree with the ones drawn earlier. For example, the data in Table 21 indicate that vehicular emissions account for approximately all of the NMHC at the Fairfax and Bethesda sites. If, in fact, this were the case, one would expect close agreement between the individual hydrocarbon/acetylene ratios obtained from the RTI data to the ratios obtained by Lonneman, et al. in the tunnel experiments. The data in Table 22 indicate the ratios for n-pentane, and isopentane are a factor of 2.3 higher than Lonneman's tunnel ratios. In the case of toluene at the Fairfax and Bethesda sites, the ratios are 6.8 times higher. The differences could be accounted for by: strong local sources of these compounds, an active sink for C_2H_2 or instrumental artifacts. An active C_2H_2 sink seems very unlikely and the available data do not provide a clear choice between the other two choices. It should be pointed out, however, that there are very large day-to-day variations in many of the ratios. Also, there is no data for a number of hydrocarbon species.

It is generally assumed that either carbon monoxide or acetylene may be used as a normalizing species for automotive emissions. As a matter of interest, the relationships between the two at the four sites are presented as scatter diagrams in Figure 51. Linear correlation coefficients between each index and concentrations of the remaining components are given in Table 24. The highest correlations between the indices and the hydrocarbon species are found with propylene, n-butane, 1-butene, iso-butane, iso-pentane and n-pentane; these correlation coefficients frequently exceed those calculated between the two indices themselves. The lowest correlations are found between the indices and ethylene/ethane, cyclopentane, and toluene.

No attempt has been made in this report to associate daily concentrations at individual sites, or concentration changes during transport, with the detailed hydrocarbon emission field. The possibility of doing so, however, could be explored using the low-level trajectories provided in Appendix E, plus the emissions data in Section III and Appendix C. If such an approach proved to be promising, a more detailed COG hydrocarbon inventory is available from the Council of Governments which lists contributions to individual districts by source category.

SECTION VII

SUMMARY AND CONCLUSIONS

The principal findings of this study to characterize the Washington, D.C. oxidant problem can be summarized as follows:

1. The emission density of both hydrocarbons and nitrogen oxides decreases rapidly with distance from the city center. Except along major highways, the emission densities drop by roughly one order of magnitude in about 8 kilometers outward from the center of Washington, and roughly another order of magnitude in an additional 16 kilometers.

2. On all but 10 days during June, July and August of 1976, the oxidant standard was equalled or exceeded at one or more monitors within the study area. No evidence was found for a trend in the number of violations; recent year-to-year variations in the severity of the oxidant problem are attributed to differences in meteorological conditions.

3. Ozone concentrations at all sites almost always behave in the classical way, with low concentrations at night, a minimum near 0600 a.m., and the daily maximum shortly after noon. When the maximum does occur at night, it rarely exceeds the standard. This suggests domination by locally generated ozone.

4. Changes in the rate of ozone formation appears to occur on an areawide scale with concentrations rising and falling in response to meteorological conditions. Thus violations usually occur at many locations within the study area on a high ozone day.

5. High ozone concentrations are typically associated with high temperatures, at least a moderate amount of solar radiation, and a slowly moving or stagnating air mass that has accumulated a variety of pollutants during its recent history.

6. Although ozone is an areawide phenomenon, substantial differences in maximum concentrations occur at nearby locations as a result of very local influences, such as strong sources of nitric oxide. The practice of monitoring ozone near heavily traveled streets and highways severely limits the usefulness of some of the data for meso and larger scale field studies.

7. No significant difference in the time of the ozone maximum was detected between the upwind and downwind edges of Washington. On the average, however, afternoon concentrations downwind were nearly 20 percent higher than concentrations upwind. Because of difficulty in eliminating the impact of localized site interferences, this conclusion should be considered provisional. Also, the main effects of Washington's emissions downstream could well be occurring outside the monitoring network.

8. An average value of 9.7 was found for the NMHC/NO_x ratio, using data from the Fairfax, Bethesda, Suitland, and CAMP sites and NMHC concentrations determined by flame ionization detection. When data from Fairfax (a residential/commercial site approximately 20 kilometers west of Washington, D.C.) was removed, the ratio was 6.7.

9. NMHC concentrations, averaged from six sites over the 0600 to 0900 a.m. period showed Saturday and Sunday concentrations to be 77 and 91 percent, respectively, of weekday concentrations.

10. Application of Lonneman's procedures for estimating the vehicular contribution to ambient NMHC concentrations was impaired by the limited number of hydrocarbon species that were measured by gas chromatographic analysis. The use of his approach with an estimate of total NMHC obtained by flame ionization detection, indicated that, on the average, vehicular emissions accounted for approximately 56, 77, 97, and 92 percent of the total NMHC measured at the Alexandria, CAMP, Fairfax, and Bethesda sites, respectively.

11. Although individual hydrocarbon/acetylene ratios varied widely at the same site, the average ratios, with the notable exceptions of ethylene/ethane and toluene, showed good agreement among sites. Comparison of the average ratios with the values reported by Lonneman from tunnel experiments showed ratios at the four study sites from 2.5 to 8 times higher than tunnel ratios for toluene;

roughly 2 times higher for n-butane, isopentane, n-pentane, and isobutane; and slightly lower for propylene. No tunnel ratio for ethylene/ethane was available for comparison. The amounts of 1-butene and cyclopentane found were too small to impact significantly on the total amount of NMHC, and were less than would have been expected from the tunnel experiments. Providing measured levels are valid, these comparisons suggest the presence of major sources of toluene (and of ethylene/ethane) in addition to motor vehicles, plus lesser, more uniformly distributed nonvehicular sources of the other principal hydrocarbon species. The lack of better agreement between the tunnel ratios and the ratios at Bethesda and Fairfax where NMHC concentrations had been estimated to be primarily from motor vehicles (see 10, above) is unexplained.

12. Although significant differences in ozone concentration were encountered in horizontal flight, aircraft sampling at an altitude of about 670 meters (2200 ft) failed to show any major increase in ozone that could be directly related to Washington's emissions. However, flight restrictions prevented a careful search for the Washington plume which may not have been located at flight altitude at the sampling distances employed.

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APPENDIX A

AIR POLLUTION ALERTS CHRONOLOGICAL HISTORY
(Provided by the Metropolitan Washington Council of Governments)

AIR POLLUTION ALERTS CHRONOLOGICAL HISTORY

Highest reading ever recorded:
August 1, 1975 -(180)in Suitland

Longest alert ever recorded:
August 25-September 6, 1973

Only winter alert:
January 18-19, 1973

Only Carbon Monoxide alert:
January 18-19, 1973

First Sunday alert:
July 8-11, 1973

Earliest hot weather alert:
April 19-21, 1976

1970

1. July 28 (oxidants)

1971

2. July 22 (oxidants)
highest reading: .124 ppm (110) recorded in Fairfax

1972

3. July 17-24 (oxidants)
highest reading: .19 ppm (145) recorded in Hyattsville on July 21.

4. August 14-15 (oxidants)
highest reading: .15 ppm (125) recorded in Bethesda on August 14.

5. August 24-27 (oxidants)
highest reading: .20 ppm (150) recorded in Hyattsville on August 26.

6. September 8-9 (oxidants)
highest reading: .19 ppm (145) recorded in Silver Spring on September 8.

Note: Numbers in parentheses indicate Air Quality Index.

1973

7. January 18-19 (carbon monoxide)
First winter alert recorded
First carbon monoxide alert
highest reading: 50 ppm (80) recorded in Bethesda on January 18.

8. June 11-12 (oxidants)
highest reading: .19 ppm (145) recorded in 7 Corners, Fairfax on June 11.

9. July 8-11 (oxidants)
highest reading: .14 ppm (120) recorded at Suitland on July 9.

10. July 18-20 (oxidants)
highest reading: .14 ppm (120) recorded in Fairfax on July 18.

11. August 6-11 (oxidants)
highest reading: .15 ppm (125) recorded at Arlington on August 10.

12. August 25-September 6 (oxidants)
Longest alert ever called
highest reading: .23 ppm (165) recorded in Alexandria on August 29.

1974

13. July 8-11 (oxidants)
highest reading: .17 ppm (135) recorded at Hyattsville on July 9.

1975

14. May 22-24 (oxidants)
highest reading: .19 ppm (145) recorded in Alexandria on May 22.

15. June 24-26 (oxidants)
highest reading: .18 ppm (140) recorded in Suitland on June 24.

16. July 23-25 (oxidants)
highest reading: .15 ppm (125) recorded in Fairfax on July 24.

17. July 29-August 5 (oxidants)
highest reading: .26 ppm (180) recorded at Suitland on August 1.

1976

18. April 19-21 (oxidants)
highest reading: .145 ppm (123) recorded at DC CAMP station on April 20.

19. June 9-13 (oxidants)
highest reading: .180 ppm (140) recorded at Alexandria on June 9.

20. June 29-30 (oxidants)
highest reading; .135 ppm (120) recorded at Alexandria on June 29.

21. July 6-7 (oxidants)
highest reading: .135 ppm (120) recorded at Alexandria on July 6.

22. August 4-6 (oxidants)
highest reading: .135 ppm (120) recorded in Bethesda on August 6.

23. August 12-15 (oxidants)
highest reading: .143 ppm (122) recorded in Bethesda on August 14.

24. August 24-27 (oxidants)
highest reading: .158 ppm (129) recorded in Bethesda on August 25.

25. September 13-15 (oxidants)
highest reading: .193 ppm (145) recorded in Bethesda on September 14.

APPENDIX B

MIXING HEIGHTS AT STERLING, VIRGINIA

The mixing heights in this appendix were calculated by EPA, using the Holzworth procedure, from the three daily soundings taken at Sterling, Virginia during July and August 1976. The morning mixing height was calculated as the height above ground at which the dry adiabatic extension of the morning minimum surface temperature plus 2°C intersected the observed vertical temperature profile. The maximum surface temperature was used in calculating the afternoon mixing height. For the 1700 GMT sounding, the surface temperature corresponding to this time period was obtained from the LCD's for Washington, D.C.

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SOUNDING   371 DATE = 6/30 TIME = 2300 MIXING HGT =    2483
SOUNDING   372 DATE = 7/01 TIME = 1100 MIXING HGT =      97
SOUNDING   373 DATE = 7/01 TIME = 1700 MIXING HGT =    2329
SOUNDING   374 DATE = 7/01 TIME = 2300 MIXING HGT =    2445
SOUNDING   375 DATE = 7/02 TIME = 1100 MIXING HGT =      40
SOUNDING   376 DATE = 7/02 TIME = 1700 MIXING HGT =    2888
SOUNDING   377 DATE = 7/02 TIME = 2300 MIXING HGT =    3377
SOUNDING   378 DATE = 7/03 TIME = 1100 MIXING HGT =      63
SOUNDING   379 DATE = 7/03 TIME = 1700 MIXING HGT =    3223
SOUNDING   380 DATE = 7/04 TIME = 1100 MIXING HGT =     327
SOUNDING   381 DATE = 7/04 TIME = 1700 MIXING HGT =    2135
SOUNDING   382 DATE = 7/04 TIME = 2300 MIXING HGT =    2263
SOUNDING   383 DATE = 7/05 TIME = 1100 MIXING HGT =     515
SOUNDING   384 DATE = 7/05 TIME = 1700 MIXING HGT =    2001
SOUNDING   385 DATE = 7/05 TIME = 2300 MIXING HGT =    2907
SOUNDING   386 DATE = 7/06 TIME = 1100 MIXING HGT =     331
SOUNDING   387 DATE = 7/06 TIME = 1700 MIXING HGT =    2026
SOUNDING   388 DATE = 7/06 TIME = 2300 MIXING HGT =    2578
SOUNDING   389 DATE = 7/07 TIME = 1100 MIXING HGT =     463
SOUNDING   390 DATE = 7/07 TIME = 1700 MIXING HGT =    1480
SOUNDING   392 DATE = 7/08 TIME = 1100 MIXING HGT =     148
SOUNDING   393 DATE = 7/08 TIME = 1700 MIXING HGT =    1366
SOUNDING   394 DATE = 7/08 TIME = 2300 MIXING HGT =    1603
SOUNDING   395 DATE = 7/09 TIME = 1100 MIXING HGT =     522
SOUNDING   396 DATE = 7/09 TIME = 1700 MIXING HGT =    2009
SOUNDING   397 DATE = 7/09 TIME = 2300 MIXING HGT =    2217
SOUNDING   398 DATE = 7/10 TIME = 1100 MIXING HGT =     117
SOUNDING   399 DATE = 7/10 TIME = 1700 MIXING HGT =    1753
SOUNDING   400 DATE = 7/10 TIME = 2300 MIXING HGT =    1448
SOUNDING   401 DATE = 7/11 TIME = 1100 MIXING HGT =      71
SOUNDING   402 DATE = 7/11 TIME = 1700 MIXING HGT =     178
SOUNDING   403 DATE = 7/11 TIME = 2300 MIXING HGT =     133
SOUNDING   404 DATE = 7/12 TIME = 1100 MIXING HGT =      28
SOUNDING   405 DATE = 7/12 TIME = 1700 MIXING HGT =    2121
SOUNDING   406 DATE = 7/12 TIME = 2300 MIXING HGT =    2617
SOUNDING   407 DATE = 7/13 TIME = 1100 MIXING HGT =     466
SOUNDING   408 DATE = 7/13 TIME = 1700 MIXING HGT =    2120
SOUNDING   409 DATE = 7/13 TIME = 2300 MIXING HGT =    2234
SOUNDING   410 DATE = 7/14 TIME = 1100 MIXING HGT =     705
SOUNDING   411 DATE = 7/14 TIME = 1700 MIXING HGT =    1213
SOUNDING   412 DATE = 7/14 TIME = 2300 MIXING HGT =    1058
SOUNDING   413 DATE = 7/15 TIME = 1100 MIXING HGT =     230
SOUNDING   414 DATE = 7/15 TIME = 2300 MIXING HGT =    1286
SOUNDING   415 DATE = 7/16 TIME = 1100 MIXING HGT =     112
SOUNDING   416 DATE = 7/16 TIME = 1700 MIXING HGT =    1901
SOUNDING   417 DATE = 7/16 TIME = 2300 MIXING HGT =    2540
SOUNDING   418 DATE = 7/17 TIME = 1100 MIXING HGT =     856
SOUNDING   419 DATE = 7/17 TIME = 1700 MIXING HGT =    2017
SOUNDING   420 DATE = 7/17 TIME = 2300 MIXING HGT =    2038
SOUNDING   421 DATE = 7/18 TIME = 1100 MIXING HGT =     110
SOUNDING   422 DATE = 7/18 TIME = 1700 MIXING HGT =    2300
SOUNDING   423 DATE = 7/18 TIME = 2300 MIXING HGT =    2697
SOUNDING   424 DATE = 7/19 TIME = 1100 MIXING HGT =      68
SOUNDING   425 DATE = 7/19 TIME = 1700 MIXING HGT =    1798
SOUNDING   426 DATE = 7/19 TIME = 2300 MIXING HGT =    2085
SOUNDING   427 DATE = 7/20 TIME = 1100 MIXING HGT =     162
SOUNDING   428 DATE = 7/20 TIME = 1700 MIXING HGT =    1063
SOUNDING   429 DATE = 7/20 TIME = 2300 MIXING HGT =    2075
SOUNDING   430 DATE = 7/21 TIME = 1100 MIXING HGT =     193
SOUNDING   431 DATE = 7/21 TIME = 1700 MIXING HGT =    1038
SOUNDING   432 DATE = 7/21 TIME = 2300 MIXING HGT =    2280
SOUNDING   433 DATE = 7/22 TIME = 1100 MIXING HGT =     375
SOUNDING   434 DATE = 7/22 TIME = 1700 MIXING HGT =     966
SOUNDING   435 DATE = 7/22 TIME = 2300 MIXING HGT =    1358
SOUNDING   436 DATE = 7/23 TIME = 1100 MIXING HGT =     439
SOUNDING   437 DATE = 7/23 TIME = 1700 MIXING HGT =    1659
SOUNDING   438 DATE = 7/23 TIME = 2300 MIXING HGT =     690
SOUNDING   439 DATE = 7/24 TIME = 1100 MIXING HGT =     322
SOUNDING   440 DATE = 7/24 TIMF = 1700 MIXING HGT =    1734
SOUNDING   441 DATE = 7/24 TIME = 2300 MIXING HGT =    2217
SOUNDING   442 DATE = 7/25 TIME = 1100 MIXING HGT =     149
SOUNDING   443 DATE = 7/25 TIME = 1700 MIXING HGT =    1575
SOUNDING   444 DATE = 7/25 TIME = 2300 MIXING HGT =    1747
SOUNDING   445 DATE = 7/26 TIME = 1100 MIXING HGT =     152
SOUNDING   446 DATE = 7/26 TIME = 1700 MIXING HGT =    1634
SOUNDING   447 DATE = 7/26 TIME = 2300 MIXING HGT =    1595
SOUNDING   448 DATE = 7/27 TIME = 1100 MIXING HGT =     235
SOUNDING   449 DATE = 7/27 TIME = 1700 MIXING HGT =    1362
SOUNDING   450 DATE = 7/27 TIME = 2300 MIXING HGT =    1695
SOUNDING   451 DATE = 7/28 TIME = 1100 MIXING HGT =     351
SOUNDING   452 DATE = 7/28 TIME = 1700 MIXING HGT =    1642
SOUNDING   453 DATE = 7/28 TIME = 2300 MIXING HGT =    2117
SOUNDING   454 DATE = 7/29 TIME = 1100 MIXING HGT =     229
SOUNDING   455 DATE = 7/29 TIME = 1700 MIXING HGT =    1297
SOUNDING   456 DATE = 7/29 TIME = 2300 MIXING HGT =    1765
SOUNDING   457 DATE = 7/30 TIME = 1100 MIXING HGT =      94
SOUNDING   458 DATE = 7/30 TIME = 1700 MIXING HGT =    1633
SOUNDING   459 DATE = 7/30 TIME = 2300 MIXING HGT =    1597
SOUNDING   460 DATE = 7/31 TIME = 1100 MIXING HGT =     145
SOUNDING   461 DATE = 7/31 TIME = 1700 MIXING HGT =    1930
SOUNDING   462 DATE = 7/31 TIME = 2300 MIXING HGT =    2011
SOUNDING   463 DATE = 8/01 TIME = 1100 MIXING HGT =     386
SOUNDING   464 DATE = 8/01 TIME = 1700 MIXING HGT =    2053
SOUNDING   465 DATE = 8/01 TIME = 2300 MIXING HGT =    2497
SOUNDING   466 DATE = 8/02 TIME = 1100 MIXING HGT =     188
SOUNDING   467 DATE = 8/02 TIME = 1700 MIXING HGT =    1806
SOUNDING   468 DATE = 8/02 TIME = 2300 MIXING HGT =    1927
SOUNDING   469 DATE = 8/03 TIME = 1100 MIXING HGT =     187
SOUNDING   470 DATE = 8/03 TIME = 1700 MIXING HGT =    2301
SOUNDING   471 DATE = 8/03 TIME = 2300 MIXING HGT =    2768
SOUNDING   472 DATE = 8/04 TIME = 1100 MIXING HGT =     172
SOUNDING   473 DATE = 8/04 TIME = 1700 MIXING HGT =    2467
SOUNDING   474 DATE = 8/04 TIME = 2300 MIXING HGT =    2305
SOUNDING   475 DATE = 8/05 TIME = 1100 MIXING HGT =     219
SOUNDING   476 DATE = 8/05 TIME = 1700 MIXING HGT =    1568
SOUNDING   477 DATE = 8/05 TIME = 2300 MIXING HGT =    2559
SOUNDING   478 DATE = 8/06 TIME = 1100 MIXING HGT =     148
SOUNDING   479 DATE = 8/06 TIME = 1700 MIXING HGT =    1904
SOUNDING   480 DATE = 8/06 TIME = 2300 MIXING HGT =    2691
SOUNDING   481 DATE = 8/07 TIME = 1100 MIXING HGT =     554
SOUNDING   482 DATE = 8/07 TIME = 1700 MIXING HGT =     504
SOUNDING   483 DATE = 8/07 TIME = 2300 MIXING HGT =     595
SOUNDING   484 DATE = 8/08 TIME = 1100 MIXING HGT =     567
SOUNDING   485 DATE = 8/08 TIME = 1700 MIXING HGT =     597
SOUNDING   486 DATE = 8/08 TIME = 2300 MIXING HGT =     830
SOUNDING   487 DATE = 8/09 TIME = 1100 MIXING HGT =     258
SOUNDING   488 DATE = 8/09 TIME = 1700 MIXING HGT =     624
SOUNDING   489 DATE = 8/09 TIME = 2300 MIXING HGT =     972
SOUNDING   490 DATE = 8/10 TIME = 1100 MIXING HGT =     190
SOUNDING   491 DATE = 8/10 TIME = 1700 MIXING HGT =    1769
SOUNDING   492 DATE = 8/10 TIME = 2300 MIXING HGT =    2136
SOUNDING   493 DATE = 8/11 TIME = 1100 MIXING HGT =     179
SOUNDING   494 DATE = 8/11 TIME = 1700 MIXING HGT =    1680
SOUNDING   495 DATE = 8/11 TIME = 2300 MIXING HGT =    1641
SOUNDING   496 DATE = 8/12 TIME = 1100 MIXING HGT =    150
SOUNDING   497 DATE = 8/12 TIME = 1700 MIXING HGT =    920
SOUNDING   498 DATE = 8/12 TIME = 2300 MIXING HGT =   1891
SOUNDING   499 DATE = 8/13 TIME = 1100 MIXING HGT =    125
SOUNDING   500 DATE = 8/13 TIME = 1700 MIXING HGT =   1698
SOUNDING   501 DATE = 8/13 TIME = 2300 MIXING HGT =   2048
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SOUNDING   503 DATE = 8/14 TIME = 1700 MIXING HGT =   1836
SOUNDING   504 DATE = 8/14 TIME = 2300 MIXING HGT =   2229
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SOUNDING   506 DATE = 8/15 TIME = 1700 MIXING HGT =     50
SOUNDING   507 DATE = 8/15 TIME = 2300 MIXING HGT =   1554
SOUNDING   508 DATE = 8/16 TIME = 1100 MIXING HGT =    555
SOUNDING   509 DATE = 8/16 TIME = 1700 MIXING HGT =   1881
SOUNDING   510 DATE = 8/16 TIME = 2300 MIXING HGT =   1780
SOUNDING   511 DATE = 8/17 TIME = 1100 MIXING HGT =    202
SOUNDING   512 DATE = 8/17 TIME = 1700 MIXING HGT =   1833
SOUNDING   513 DATE = 8/17 TIME = 2300 MIXING HGT =   1917
SOUNDING   514 DATE = 8/18 TIME = 1100 MIXING HGT =     91
SOUNDING   515 DATE = 8/18 TIME = 1700 MIXING HGT =   1858
SOUNDING   516 DATE = 8/18 TIME = 2300 MIXING HGT =   2400
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SOUNDING   518 DATE = 8/19 TIME = 1700 MIXING HGT =   1862
SOUNDING   519 DATE = 8/19 TIME = 2300 MIXING HGT =   1737
SOUNDING   520 DATE = 8/20 TIME = 1100 MIXING HGT =    222
SOUNDING   521 DATE = 8/20 TIME = 1700 MIXING HGT =   1268
SOUNDING   522 DATE = 8/20 TIME = 2300 MIXING HGT =   1203
SOUNDING   523 DATE = 8/21 TIME = 1100 MIXING HGT =    218
SOUNDING   524 DATE = 8/21 TIME = 1700 MIXING HGT =   1132
SOUNDING   525 DATE = 8/21 TIME = 2300 MIXING HGT =   1127
SOUNDING   526 DATE = 8/22 TIME = 1100 MIXING HGT =    751
SOUNDING   527 DATE = 8/22 TIME = 1700 MIXING HGT =   1092
SOUNDING   528 DATE = 8/22 TIME = 2300 MIXING HGT =   1589
SOUNDING   529 DATE = 8/23 TIME = 1100 MIXING HGT =    265
SOUNDING   530 DATE = 8/23 TIME = 1700 MIXING HGT =   1169
SOUNDING   531 DATE = 8/23 TIME = 2300 MIXING HGT =   1405
SOUNDING   532 DATE = 8/24 TIME = 1100 MIXING HGT =    308
SOUNDING   533 DATE = 8/24 TIME = 1700 MIXING HGT =   1795
SOUNDING   534 DATE = 8/24 TIME = 2300 MIXING HGT =   1655
SOUNDING   535 DATE = 8/25 TIME = 1100 MIXING HGT =    504
SOUNDING   536 DATE = 8/25 TIME = 1700 MIXING HGT =   1030
SOUNDING   537 DATE = 8/25 TIME = 2300 MIXING HGT =   1388
SOUNDING   538 DATE = 8/26 TIME = 1100 MIXING HGT =    272
SOUNDING   539 DATE = 8/26 TIME = 1700 MIXING HGT =    752
SOUNDING   540 DATE = 8/26 TIME = 2300 MIXING HGT =   1773
SOUNDING   541 DATE = 8/27 TIME = 1100 MIXING HGT =    430
SOUNDING   542 DATE = 8/27 TIME = 1700 MIXING HGT =   1116
SOUNDING   543 DATE = 8/27 TIME = 2300 MIXING HGT =   1099
SOUNDING   544 DATE = 8/28 TIME = 1100 MIXING HGT =    397
SOUNDING   545 DATE = 8/28 TIME = 1700 MIXING HGT =    818
SOUNDING   546 DATE = 8/28 TIME = 2300 MIXING HGT =   1072
SOUNDING   547 DATE = 8/29 TIME = 1100 MIXING HGT =    118
SOUNDING   548 DATE = 8/29 TIME = 1700 MIXING HGT =   1922
SOUNDING   549 DATE = 8/29 TIME = 2300 MIXING HGT =   2333
SOUNDING   550 DATE = 8/30 TIME = 1100 MIXING HGT =    851
SOUNDING   551 DATE = 8/30 TIME = 1700 MIXING HGT =   1559
SOUNDING   552 DATE = 8/30 TIME = 2300 MIXING HGT =   1647
SOUNDING   553 DATE = 8/31 TIME = 1100 MIXING HGT =    299
SOUNDING   554 DATE = 8/31 TIME = 1700 MIXING HGT =   1619
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APPENDIX C

AREA AND POINT SOURCE EMISSIONS OF HYDROCARBONS AND NITROGEN OXIDES

(1973 inventory as supplied by the Metropolitan Washington Council of Governments. Area emissions are by Policy Analysis Districts.)

Table C-1. POINT SOURCE EMISSIONS OF NITROGEN OXIDES

Maryland coordinates, xxx, yyy	NO_x T/Y x 10^2	Stack ht., ft x 10	Stack diam., ft x 10	Stack vel., ft/sec x 10	Stack temp., F x 10	Source name
718257	71200	210	300	82	8900	POSSUM PT 6-11
783390	53250	1320	132	114	6000	WEST HEAT PT
799371	4830	2350	157	80	5500	ST ELIZ HOSP
799371	8237	2280	147	100	4195	ST ELIZ HOSP
803383	76900	1340	202	103	6000	CENTRAL HT PT
799382	24700	1670	225	110	3450	CAPITOL PR PT
784308	5600	1700	250	110	5000	ARL CY INCIN
766354	9600	2000	250	98	5000	ALEX INCIN
812388	62600	1770	416	110	2420	BENNING 1
799379	1280	2040	300	120	3000	WASH NAVY YD
718256	222800	1770	421	130	2620	POSSUM PT 3
718256	192000	1750	352	130	2950	POSSUM PT 2
812388	99700	1770	774	85	3100	BENNING 2
693253	1300	310	304	30	4500	MCB QUANTICO
710240	203	470	126	30	3500	MCB QUANTICO
797377	17000	1780	221	160	3760	BUZZ 1,2
812388	48300	2410	982	75	3500	BENNING 4
797377	96000	400	650	43	9300	BUZZ SGT 1-16
799379	24870	2040	440	120	4000	WASH NAVY YD
799379	1280	2040	440	120	4000	WASH NAVY YD
718256	180100	1750	410	130	3540	POSSUM PT 1
813387	48800	2000	203	180	4500	SOL WAS RC 1
718256	476300	1750	704	130	2580	POSSUM PT 4
797377	43000	1780	374	160	5500	BUZZ 3-6
680505	480300	4000	407	165	2460	DICKERSON 2
680505	960700	4000	793	165	2460	DICKERSON 1
812388	114600	2410	132	125	6500	BENNING 3
890258	1372000	4000	710	260	2440	CHALK PT
761309	1633	400	216	55	5500	FORT BELVOIR
761309	3266	400	218	55	4550	FORT BELVOIR
729315	4700	600	300	25	4600	LORTON REFORM
731321	9800	600	300	25	5000	LORTON REFORM
810433	210	400	200	40	4000	NAV ORD LAB
810433	4430	750	200	40	4000	NAV ORD LAB
771424	750	500	150	30	1500	NIH BETHESDA
800401	2100	450	156	28	6100	CATHOLIC U
800401	900	730	96	33	5000	CATHOLIC U
787372	5600	235	6	50	3750	NAT AIRPORT
836554	350	600	150	30	1500	ANDREWS AFB
810433	420	150	200	40	4000	NAV ORD LAB

Table C-1 (continued). POINT SOURCE EMISSIONS OF NITROGEN OXIDES

Maryland coordinates, xxx, yyy	NO_x T/Y x 10^2	Stack ht., ft x 10	Stack diam., ft x 10	Stack vel., ft/sec x 10	Stack temp., F x 10	Source name
713249	9660	770	50	200	3630	MCB QUANTICO
710240	2813	470	30	500	4500	MCB QUANTICO
655335	4500	600	45	149	3240	IBM MANASSAS
756316	3600	480	30	387	5400	FORT BELVOIR
772379	3300	360	40	300	5000	FORT MYER
772379	400	1150	40	62	3500	FORT MYER
830436	1660	400	40	300	4000	AGRIC RES CT
836354	220	150	40	300	4000	ANDREWS AFB
836354	9897	400	40	300	5000	ANDREWS AFB
836354	8245	750	40	200	5000	ANDREWS AFB
834446	2150	750	45	130	5300	MIN PIG CORP
834446	100	1250	35	100	6000	MIN PIG CORP
810433	350	920	30	200	5000	NAV ORD LAB
773425	23850	1750	40	200	4000	NAT NAV MD CT
771424	19000	750	40	300	3300	NIH BETHESDA
778392	5850	500	50	270	3050	GEORGETOWN U
796367	4290	400	40	315	4000	BOLLING AFB
801379	2815	600	50	200	4000	ANACOSTIA NS
713249	11340	900	60	200	3500	MCB QUANTICO
798389	14800	1500	49	190	4500	WASH TERM CO
785377	9175	700	40	530	5760	PENTAGON PP
785377	18350	700	40	650	5900	PENTAGON PP
830436	3758	1750	40	300	4000	AGRIC RES CT
717252	800	1430	60	300	4000	MCB QUANTICO
730314	800	1400	70	232	3500	LORTON REFORM
785377	9175	700	40	770	6110	PENTAGON PP
830436	130	2250	40	300	4000	AGRIC RES CT
763463	36600	860	107	100	6000	MC MUN INCIN
793360	11810	530	45	560	6000	NAVAL RES LAB
795398	6410	927	95	124	5000	WASH HOSP CT
791416	5200	1500	70	229	5550	WALT REED AMC
796401	4140	1850	90	75	5820	US SOLD HOME
796401	730	1750	90	75	4940	US SOLD HOME
808382	5000	1250	80	154	4400	DC GEN HOSP
795398	90	927	42	191	2000	WASH HOSP CT
788355	611400	1090	80	400	2500	POTOMAC 3-5
801379	1410	350	15	400	4000	ANACOSTIA NS
794398	7020	1280	50	512	5000	HOWARD UNIV
791416	5200	1500	70	224	5550	WALT REED AMC
788355	185100	1090	80	385	3300	POTOMAC 1, 2

Table C-2. AREA SOURCE EMISSIONS

Planning district	HC emissions, tons/6-9 a.m.	NO_x emissions, tons/6-9 a.m.	Area, acres
1	0.4014	0.2174	226.
2	0.5236	0.2544	225.
3	0.6095	0.2819	204.
4	0.3259	0.1461	193.
5	0.2983	0.1630	153.
6	0.3892	0.1998	194.
101	0.3214	0.1559	368.
102	0.3488	0.1438	316.
103	0.5355	0.2466	518.
104	0.4342	0.2616	265.
105	0.4016	0.2196	547.
106	0.1617	0.0702	275.
107	0.4294	0.2177	494.
108	0.1482	0.0876	714.
131	0.6019	0.3860	276.
132	0.3329	0.1519	1197.
133	0.3749	0.1830	288.
200	0.6165	0.4985	1157.
201	0.9273	0.4301	2124.
202	0.8347	0.4072	1711.
203	0.7671	0.3112	1232.
204	0.5404	0.2298	724.
205	0.5757	0.2915	1764.
206	0.2750	0.2404	619.
207	0.7843	0.3962	1566.
208	0.3413	0.1563	813.
209	0.5441	0.3865	774.
231	0.6772	0.6238	1189.
232	0.7532	0.5293	1166.
233	0.1718	0.0625	686.
234	0.3502	0.2052	417.
235	0.6505	0.2453	1502.
236	0.1212	0.0629	395.
237	0.1795	0.1639	940.
300	0.3011	0.2012	1929.
301	0.3974	0.1696	1900.
302	0.3842	0.1803	489.
303	0.4929	0.2688	3317.
304	1.1007	0.5365	2541.
305	0.9866	0.3923	2291.
306	0.3177	0.2292	1071.
307	1.0056	0.7625	2926.
308	0.4968	0.2710	2144.
309	1.2875	0.6851	4259.
332	0.1352	0.1115	177.
333	0.4653	0.1996	1317.
334	0.4133	0.2868	1003.
335	0.3117	0.1328	1484.
336	0.3999	0.1718	2652.
337	0.2174	0.1234	1821.

Table C-2 (continued). AREA SOURCE EMISSIONS

Planning district	HC emissions, tons/6-9 a.m.	NO_x emissions, tons/6-9 a.m.	Area, acres
381	0.6648	0.4834	1177.
382	0.7400	0.3620	2630.
411	0.7625	0.4679	3820.
412	1.3678	0.7625	5874.
413	0.8170	0.6167	1773.
414	0.7220	0.4764	2584.
415	0.7589	0.4905	1073.
416	1.3620	0.8636	3407.
421	1.1715	0.7512	4733.
422	1.4620	0.5786	5265.
423	1.9574	1.1596	8118.
424	1.4340	1.1238	4990.
425	1.2093	0.7530	7746.
426	1.2880	0.7695	7606.
427	0.9663	0.6142	5583.
428	1.1047	0.7502	4548.
429	0.3760	0.1336	858.
442	1.2423	0.7755	4433.
443	0.3370	0.1424	1233.
452	0.7252	0.8192	1005.
453	0.8999	0.3981	10815.
454	1.5005	0.9526	7074.
455	1.2474	0.7983	6090.
456	0.7111	0.4245	4071.
457	0.6905	0.6223	5878.
511	0.1265	0.0842	5268.
512	0.7235	0.5237	7092.
513	0.8689	0.5222	5243.
514	0.8142	0.3986	2582.
515	0.8698	0.5141	5714.
516	0.6367	0.3716	5288.
521	0.2968	0.1584	3392.
523	0.3498	0.1802	4159.
524	0.6626	0.3574	12733.
525	0.1446	0.1088	6126.
526	0.1769	0.1217	11604.
527	1.6480	0.3917	7930.
528	0.9342	0.4325	16026.
529	0.1441	0.0465	7622.
541	0.0118	0.0023	138.
551	0.6734	0.3128	8013.
552	1.6625	0.9973	23023.
553	0.9970	0.6844	8169.
554	0.2494	0.3690	6589.
555	0.6968	0.3696	9977.
556	0.4794	0.3397	3498.
557	0.3762	0.2524	6881.
611	0.6895	0.0485	9796.
612	0.6049	0.4796	8121.
613	1.9563	0.5483	5286.

Table C-2 (continued). AREA SOURCE EMISSIONS

Planning district	HC emissions, tons/6-9 a.m.	NO_x emissions, tons/6-9 a.m.	Area acres
614	0.9483	0.4207	14837.
615	0.6595	0.4522	14189.
616	0.3901	0.2730	15289.
621	0.9922	0.8204	9365.
623	0.7456	0.5612	6797.
624	0.7188	0.4958	21789.
625	0.5302	0.4798	15043.
626	0.2698	0.2187	22382.
627	0.1802	0.1200	18901.
628	0.2998	0.2974	19381.
629	0.1326	0.1075	7043.
651	0.4133	0.1339	11242.
653	0.5938	0.6714	16915.
654	0.5750	0.3107	10321.
655	0.6234	0.4284	4299.
656	0.1726	0.1279	12763.
657	0.1988	0.1457	12681.
711	0.0368	0.0204	17200.
712	0.2298	0.1244	18802.
713	1.1014	0.9722	17199.
714	0.0764	0.0595	8283.
715	0.1534	0.1422	14452.
751	0.0793	0.0756	8265.
753	0.1379	0.1348	16342.
754	0.3362	0.4253	20190.
755	0.3716	0.3688	19782.
756	0.3237	0.3026	16420.
757	0.3028	0.1644	16512.
766	0.2864	0.2814	7549.
767	0.2246	0.1642	19200.
771	0.8470	0.7078	7456.
773	0.6612	0.4262	44305.
774	0.5788	0.3129	12490.
775	0.0850	0.0135	2088.
811	0.0150	0.0088	40240.
812	0.0180	0.0155	31065.
813	0.0434	0.0309	50498.
827	0.0634	0.0326	64919.
828	0.0110	0.0067	8594.
865	0.0189	0.0131	77775.
866	0.1079	0.0656	134111.
867	0.0394	0.0271	92259.
871	0.1496	0.0709	18707.
873	0.0346	0.0123	70240.
874	0.0178	0.0169	27142.
875	0.0221	0.0240	42846.

APPENDIX D

CHARACTERISTICS OF MONITOR SITES

These written comments were received from local agencies following discussions concerning possible local influences on oxidant measurements.

Department of Environmental Protection

MONTGOMERY COUNTY, MARYLAND

ROOM 320 • 6110 EXECUTIVE BOULEVARD, ROCKVILLE, MARYLAND 20852

March 30, 1977

Mr. Frank Record
GCA/Technology Division
Burlington Road
Bedford Road
Bedford, Mass. 01730

Dear Mr. Record;

On March 29, 1977 you requested an agency statement concerning the manner in which the ozone data provided to you for the intersection of Deer Park Drive and Frederick Road (Highway Route 355) was obtained. Enclosure (1) provides you with the horizontal dimensions and the direction of True North. The monitoring facility lies in a depression at the upper end of the Muddy Branch drainage basin which drains to the southwest.

The data was obtained using a McMillan Electronics Company Series 1100 Ozone Monitor calibrated using the neutrally-buffered potassium iodide method and a McMillan 1100A Ozone Generator.

Because monitoring was accomplished next to an intersection, enclosure (2) is forwarded providing traffic counts for July 26, 1976 at that intersection. It has been observed that the carbon monoxide level, which is monitored at an adjacent station, rises and falls with the movement of the traffic at that intersection. The intersection traffic volume rises during the rush hours.

It should be noted that due to a change in air monitoring policy by the Department of Environmental Protection, there will be no air pollution monitoring at this intersection during the summer of 1977.

If I can be of further assistance to you, please keep me advised.

Very truly yours,

Robert E. Lee

Robert E. Lee, Chief
Division of Research and Monitoring
Department of Environmental Protection

REL:pmd

Encl: (1) Location of Ozone and CO Probes w/respect to Intersection
(2) Traffic movement graphic summary, Deer Park & Fred. Rd. 7/29/76

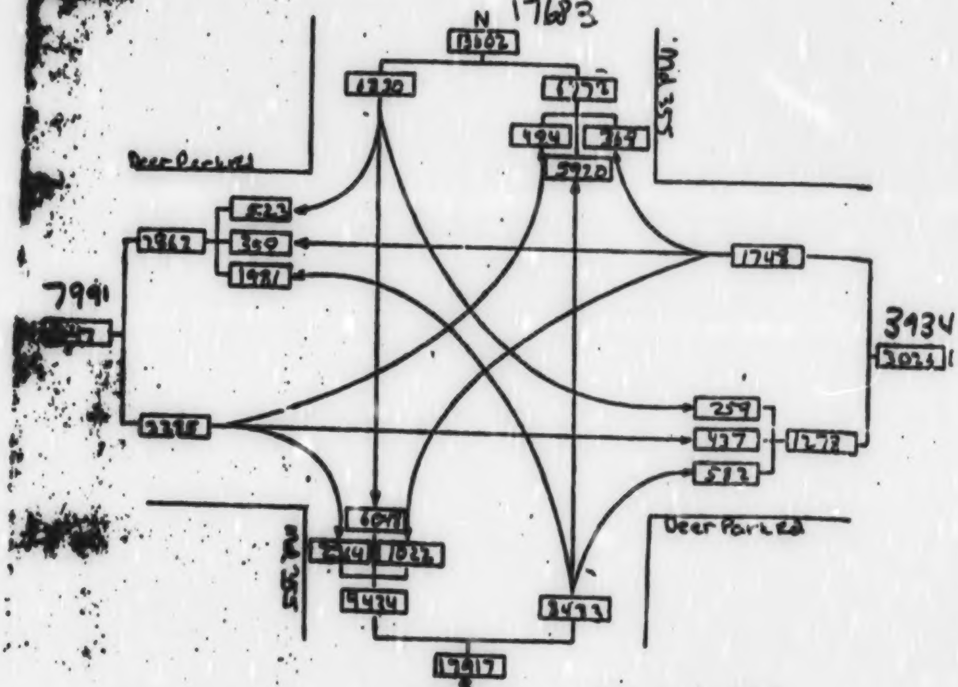
cc: 10.2.6
1.10.2

File DEER PARK DR + FREDERICK Rd. (355)

STATE HIGHWAY ADMINISTRATION OF MARYLAND

BUREAU OF TRAFFIC ENGINEERING

TRAFFIC MOVEMENT GRAPHIC SUMMARY


N
17683
13602
1220
6773
494
269
5920
Md 355
Deer Park Rd
523
300
2862
1981
7991
1748
3934
3023
259
437
1273
513
2218
6049
2264
1022
5434
3493
Md 355
Deer Park Rd
17917
S

23292 ③ ADT 1.30

Day: Thursday

Date: 7/29/76

Location: Md 355 and Deer Pk Dr.

Remarks:

SHA 22.3-69
8-14-75

State Highway Administration of Maryland
Bureau of Traffic Engineering
Record of Intersection Count

Location Md 355 and Deer Park Dr

Date & Day 7/29/76 Thursday

Requested by S Clemens Compiled by C Evans

CODED.

County Montgomery

Weather Clear

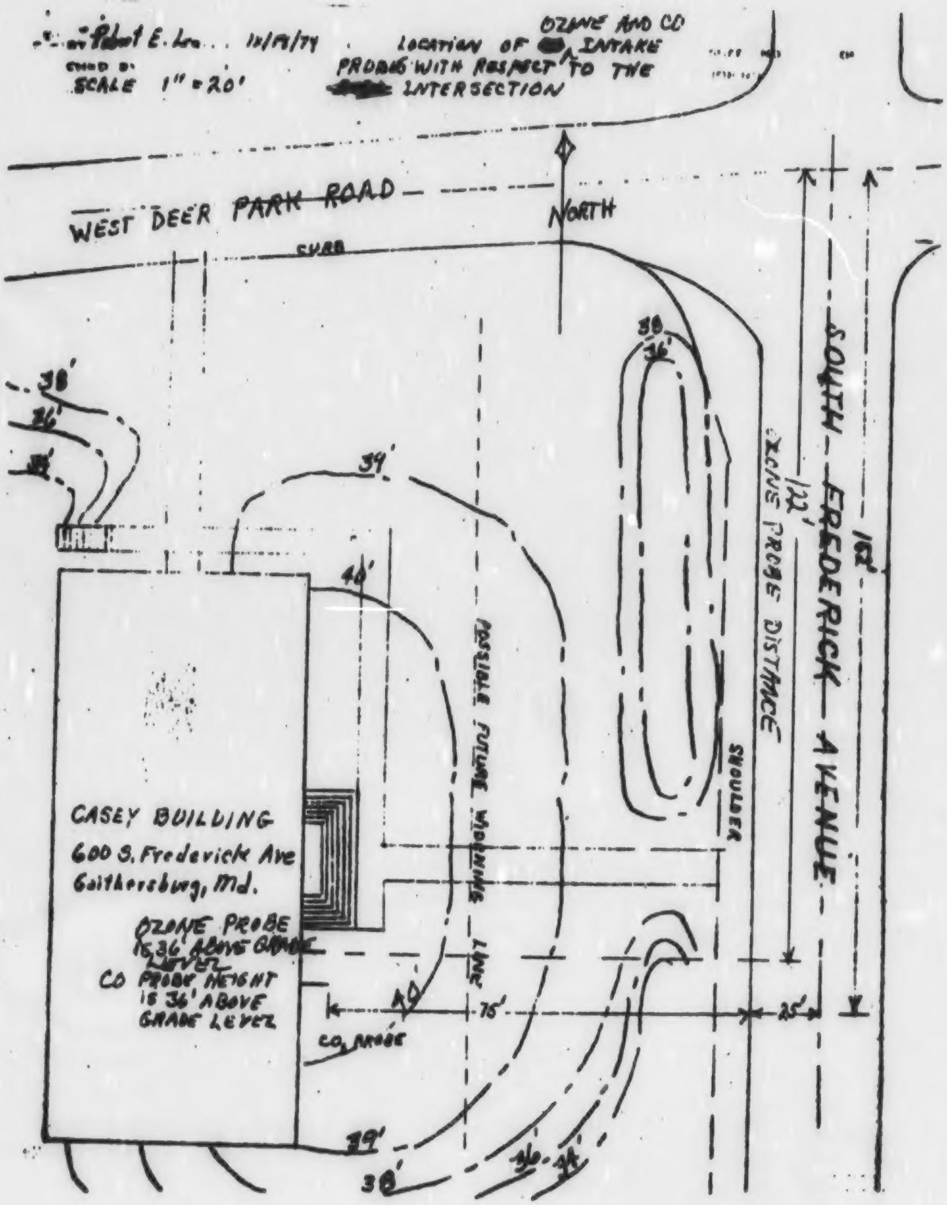
Recorder Miller

Hours Counted 7am to 7pm

Town Gaithersburg

TRAFFIC MOVEMENT SUMMARY TABLE

Name of Streets	Md 355				Md 355				Deer Park Dr				Deer Park Dr				Grand Total
	From North				From South				From East				From West				
Time	L	S	R	Tot.	L	S	R	Tot.	L	S	R	Tot.	L	S	R	Tot.	
6-7																	
7-8	21	922	33	976	62	358	16	436	239	22	19	280	47	52	511	610	2302
8-9	29	556	43	628	145	458	23	626	165	39	32	236	39	30	310	379	1869
9-10	23	447	38	508	89	421	39	549	60	27	26	113	46	20	168	234	1404
10-11	17	430	35	482	86	448	30	564	59	17	40	116	31	14	140	185	1347
11-12	32	438	26	496	90	398	36	524	66	18	30	114	40	22	124	186	132
12-1	24	488	36	548	130	474	44	648	60	22	24	106	26	24	134	184	14
1-2	26	730	77	833	199	712	65	976	99	26	36	161	51	32	203	286	225
2-3	21	450	40	511	134	484	46	664	40	14	23	77	26	20	112	158	141
3-4	18	456	39	513	172	481	60	713	48	27	24	99	50	31	129	210	153
4-5	11	443	55	509	279	702	66	1047	85	48	43	176	42	90	200	332	20
5-6	17	378	69	464	370	564	92	1026	56	56	40	152	45	51	179	275	19
6-7	20	310	32	362	245	420	45	710	45	42	31	118	41	45	154	240	143
7-8																	
8-9																	
[illegible]	259	6048	523	6830	[illegible]	5920	562	8483	1022	358	368	1748	484	437	2364	3285	[illegible]

BY Robert E. Lee 11/19/79
CHKD BY
SCALE 1" = 20'
LOCATION OF OZONE AND CO INTAKE PROBES WITH RESPECT TO THE INTERSECTION
WEST DEER PARK ROAD
CURB
NORTH
SOUTH FREDERICK AVENUE
OZONE PROBE DISTANCE
122'
162'
SHOULDER
POSSIBLE FUTURE WIDENING LINE
75'
25'
CO PROBE
38'
36'
34'
40'
39'
CASEY BUILDING
600 S. Frederick Ave
Gaithersburg, Md.
OZONE PROBE IS 36' ABOVE GRADE LEVEL
CO PROBE HEIGHT IS 36' ABOVE GRADE LEVEL

State of Maryland

DEPARTMENT OF HEALTH AND MENTAL HYGIENE
ENVIRONMENTAL HEALTH ADMINISTRATION
P.O. BOX 13387
201 WEST PRESTON STREET
BALTIMORE, MARYLAND 21203
PHONE • 301-383- 3460

NEIL SOLOMON, M.D., PH.D.
SECRETARY

DONALD H. NOREN
DIRECTOR

March 30, 1977

Mr. Frank Record
GCA/Technology Division
Burlington Road
Bedord, Massachusetts 01730

Dear Sir:

As per our conversation of this morning, included herein is the information requested regarding locations of our four air monitoring stations in the metropolitan Washington area.

There are four AIRMON remote monitoring stations in the subject area. Two of these stations are located in Prince George's County and they are designated as Suitland #03 and Cheverly #04. Similarly, there are two stations in Montgomery County and they are designated as Argyle/Sligo #05 and NIH/Bethesda #06. Each of these remote stations is a small 8 x 16 feet in plot size building with sampling probe opening approximately 13 feet above ground level.

Suitland #03 is located on the U.S. Census Bureau property in a field off of Suitland Road (Route #218). Suitland Road runs north and south; and the remote station is located approximately 170 feet west of this road. I should also note that it is not a heavily traveled road. There are no other similar roads within 500 feet of the station.

Cheverly #04 is located on the property of the Cheverly Community Park, i.e., Town of Cheverly property. The nearest road is John Hanson Highway (Route #50); and the station is directly west of the road at this point. The probe opening is approximately 80 feet from the edge of this highway; however, I should note that the highway is lower than the station and that there is a steep bank between the highway property and the property on which the station is located.

Argyle/Sligo #05 is in the Silver Spring area of Maryland. It is located on the Argyle Sligo Recreation Center. To get into this property one comes off Forest Green Road through a driveway to the back part of the property where the station is located. Forest Green Road is a residential street, and the station is over 500 feet due south of Forest Green Road. However, the property is bounded by the Baltimore/Washington Expressway (Route #495) along its southern property line; and the station probe is within 30 to 50 feet from the edge of Route #495. There is a steep embankment, and the station sits up on the level part of said embankment. As you can see, the station is due north of this heavily traveled highway.

NIH/Bethesda #06 is located on an old golf course of the National Institute of Health property, which is a large government complex whose main entrance is off of Georgia Avenue. The rear of the property is bounded by Roosevelt Street. The station is more than a thousand feet south of Georgia Avenue and more than 250 feet north of Roosevelt Street.

Of the four stations, we believe that the photochemical oxidant data generated at our Suitland #03 and NIH/Bethesda #06 stations are not influenced by vehicular emissions. Similarly, we believe that the data generated at our Cheverly #04 station is not influenced to any significant amount by said activity. The data generated at Argyle/Sligo #05, we believe, is definitely affected. We have noticed the effect of nitric oxide scavenging. Also, even though we are measuring nitrogen dioxide by a now not considered appropriate method analyzer, we have observed that the nitrogen dioxide levels at this station tend to be higher than those at our other stations. I, therefore, would caution the use of photochemical oxidant data generated at Argyle/Sligo #05 in your report.

In closing, I hope that this is the information you desired and that it will be of value to you. I would appreciate receiving a copy of this report if you can supply same.

Very truly yours,

Bob Beman

Robert H. Beman, Chief,
Division of Air Monitoring
Bureau of Air Quality
and Noise Control

cc: George P. Ferreri
Doug Proctor

RHB:pmf

FAIRFAX COUNTY HEALTH DEPARTMENT
AIR POLLUTION CONTROL
4080 CHAIN BRIDGE ROAD
FAIRFAX, VIRGINIA 22030

AIR POLLUTION CONTROL

PHONE: 691-2541

April 4, 1977

Dr. Frank Record
GCA Technical Division
Burlington Road
Bedford, Massachusetts 01730

Dear Dr. Record:

This is in response to your telephone request for information concerning the physical and geographical location of our Continuous Monitoring Stations and road networks in the immediate vicinity.

Seven Corners

The Seven Corners station is located near the SW corner of the roof parking area of a 2-story department store. The grade north of the building is slightly higher than roof level. Parking on the roof is principally by store employees; transient (customer) parking is principally south of building. There are 3 major traffic arteries in the vicinity. Wilson Blvd. (17,000 vehicles per day, 1975) is 1500 ft. north, Route 50 (41,500 veh/da) is 350 ft. southwest and Route 7 (31,000 veh/da) is one-half mile southwest. These routes intersect approximately 0.7 miles WNW of the station. The intersection is surrounded by commercial development that extends outward some 0.4 miles between Routes 50 and 7. A mixture of high-rise, low-rise and single residential occupies all non-commercial areas.

Engleside

The Engleside station is located on flat terrain 80 ft. NW of a major traffic artery (Route 1) that is lined on both sides by nearly continuous strips of small business establishments. An oil-heated school is across the highway, and the remainder of the area is occupied principally by single-family residences. Traffic on Route 1 averaged 24,000 veh/da in 1975. A small parking lot 50 ft. west of the station contains a gasoline pump used only for police vehicles.

Massey

The Massey station is located adjacent to and slightly above a limited access police parking lot that contains a gasoline pump. Lot grade is somewhat depressed, which may reduce ventilation during periods of atmospheric stagnation. Nearest major highways are Route 236 (26,000 veh/da) 1000 ft. to the north, and Route 123 (15,000 veh/da) 1100 ft. east. Development is single-family residential south and west of the station; office and limited commercial north and east.

Lewinsville

The Lewinsville station is located on the edge of a police parking lot in open and slightly elevated terrain. A gasoline pump is approximately 250 ft. away. There are no developments in the immediate vicinity, but scattered single-family dwellings are south and east; extensive office-type development is 0.7 miles west, and a major shopping center is 1.5 miles west. Route 123 (32,000 veh/da) is 260 ft. south of the station, and Lewinsville Road (10,000 veh/da) intersects Route 123 450 ft. west. The Capital Beltway (82,000 veh/da) passes 0.6 miles WNW of the station.

Note: Traffic data are based on counts made during C.Y. 1975.

Sincerely,

D G Helms

Daniel G. Helms, Director
Air Pollution Control Division

DGH/slp

GOVERNMENT OF THE DISTRICT OF COLUMBIA
DEPARTMENT OF ENVIRONMENTAL SERVICES
ENVIRONMENTAL HEALTH ADMINISTRATION
WASHINGTON, D. C. 20002

April 5, 1977

Dr. Frank Record
GCA/Technology Division
Burlington Road
Bedford, Massachusetts 01730

Dear Frank:

Our ozone monitoring sites were chosen to be as free from automotive traffic as possible to avoid a problem with nitric oxide removing ozone from the air. The discussion given below rates the sites from best to worst in the way they fulfill this.

(1) Melvin Sharpe Health School

This station is set well back from a street used primarily for rush hour activity.

(2) West End Library

This station is on the corner of two lightly travelled streets and is about a block away from a heavily travelled but wide street.

(3) Cleveland Park Library

This station is on a heavily travelled street but the probe is elevated and set back from the street.

(4) CAMP STATION

There is a lot of traffic on this street, and since last summer, considerable amount of idling of taxicabs across the street.

(5) D. C. General Hospital

Although this site is set well back from heavily travelled streets the probe is quite long.

I hope this will be of help to you.

Sincerely,

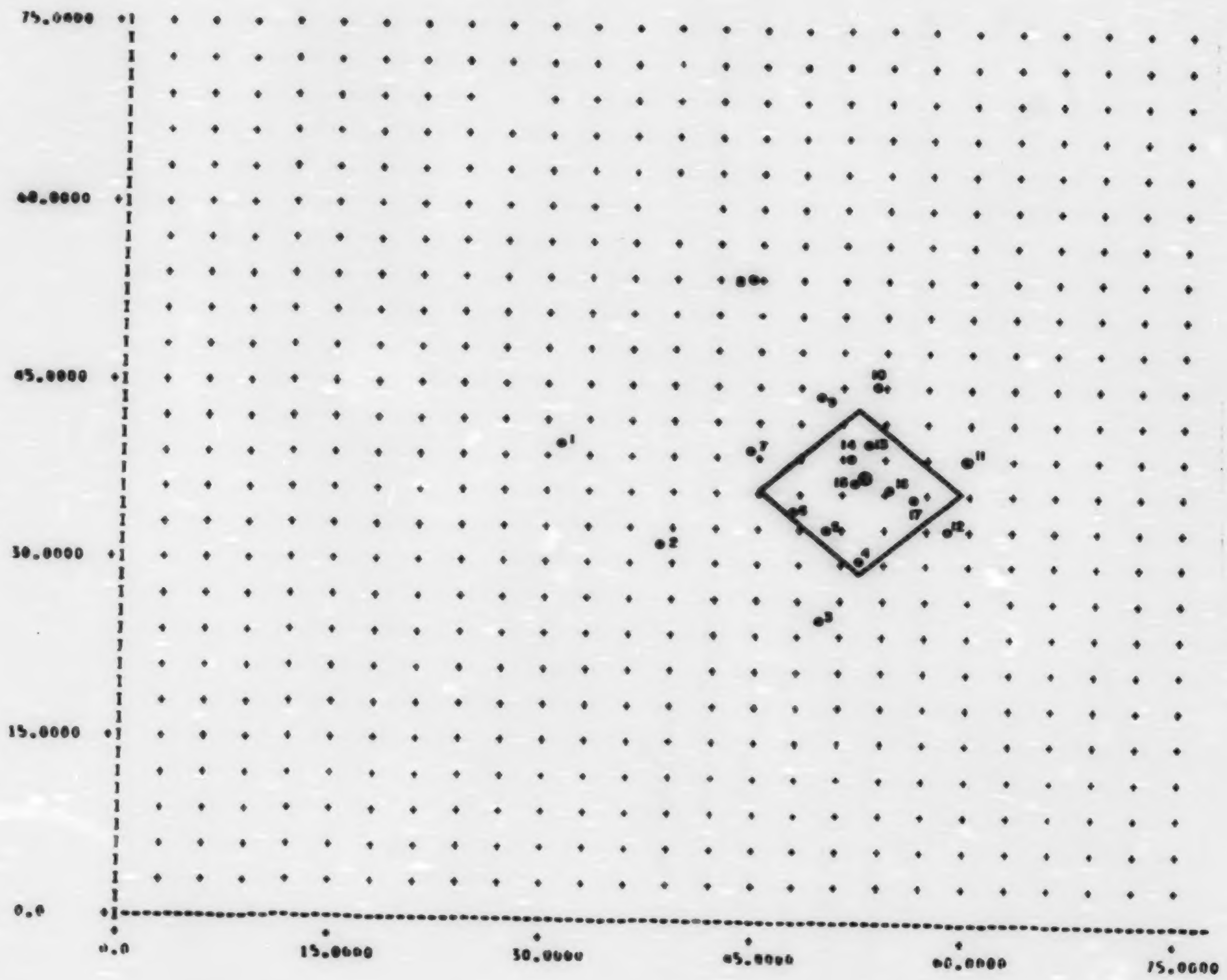
ENVIRONMENTAL HEALTH ADMINISTRATION
BAILUS WALKER, JR., PH.D., M. P. H.
Administrator

Herbert T. Wood, Ph.D., Chief
Air Monitoring Division
Bureau of Air and Water Quality Control

APPENDIX E

TRAJECTORIES

These trajectories were calculated using the trajectory subroutine of the DIFKIN model. Hourly positions are indicated by the sequence of letters, beginning with A. The calculations were performed so that the trajectory would pass over a central point in Washington, D.C. at 1400 EST. The first figure locates the Washington, D.C. "square", the central point and the ozone monitoring stations. Note that the x and y scales of the grid are not identical.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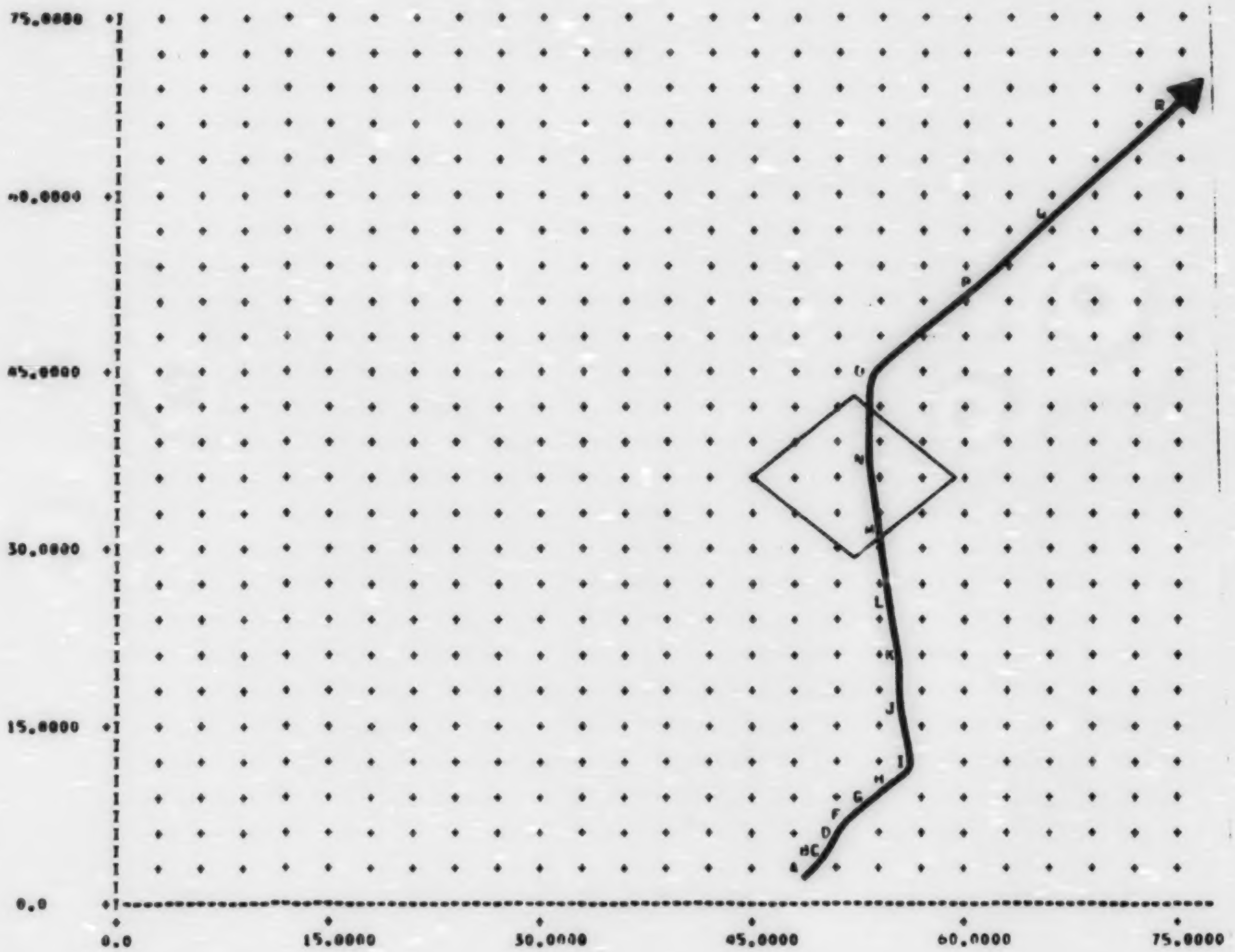
18

Note: Seventy-five mile square grid for use in trajectory calculations. Numbered locations are ozone monitoring stations


75.0000
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45.0000
30.0000
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0.0
0.0
15.0000
30.0000
45.0000
60.0000
75.0000
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Q
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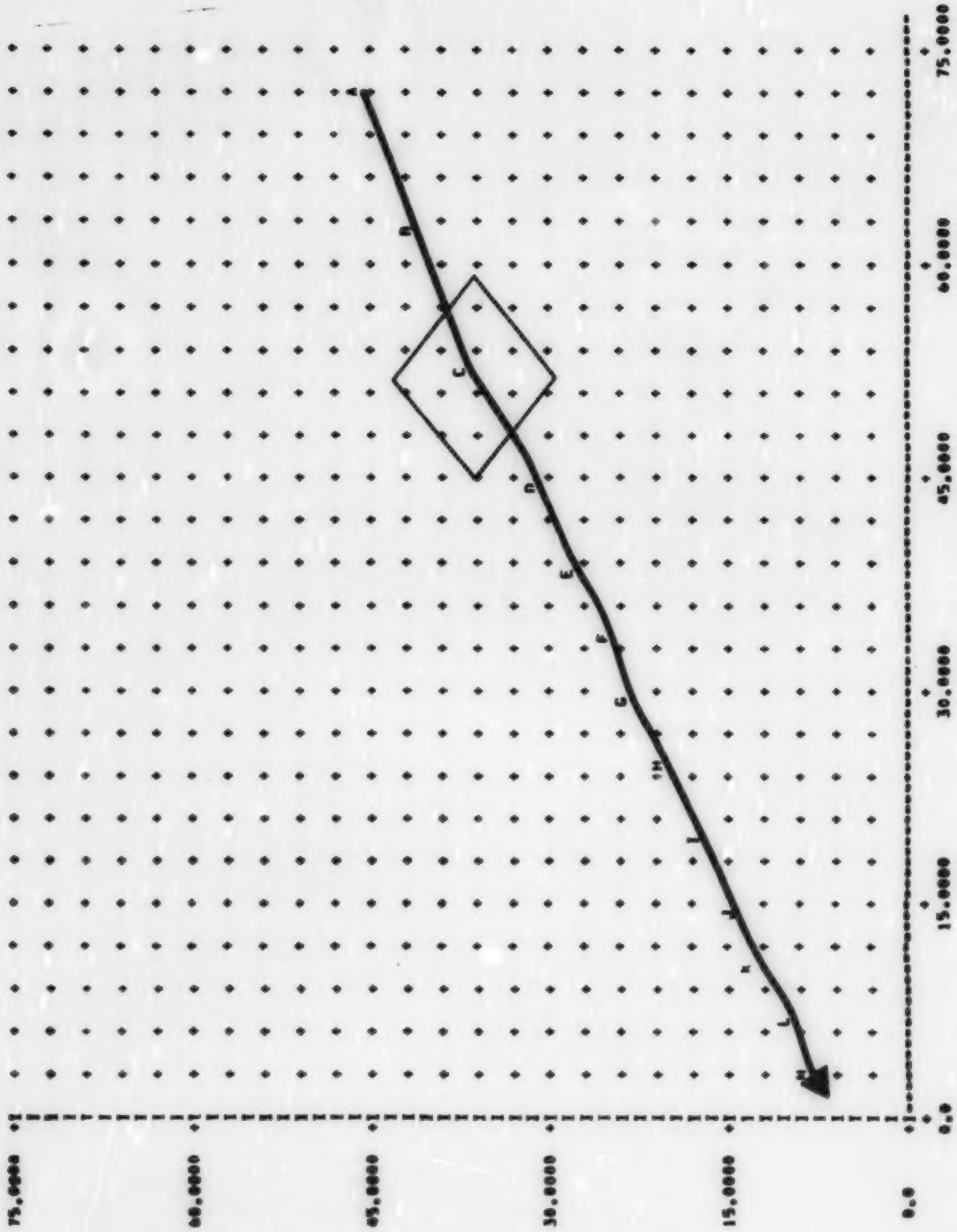
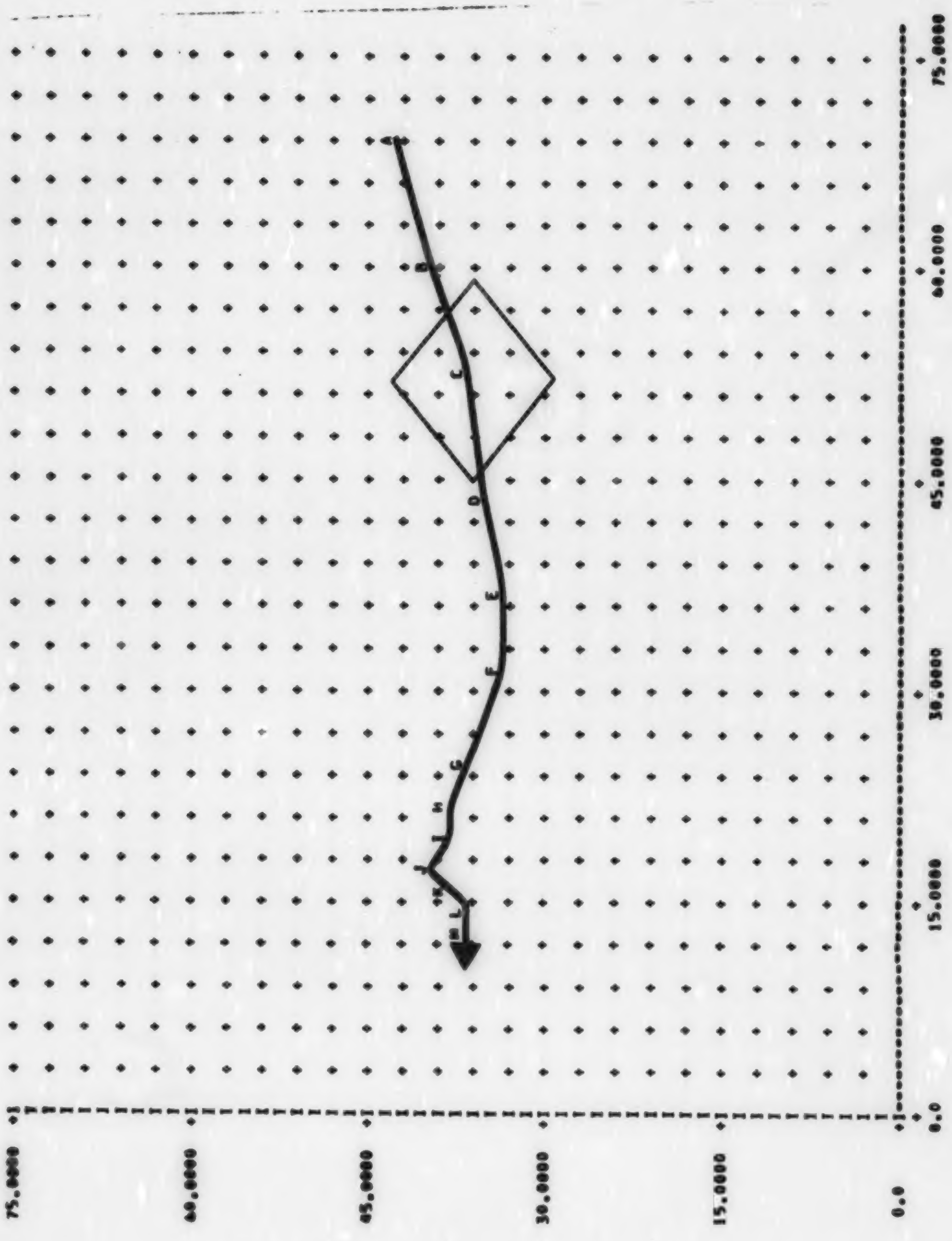
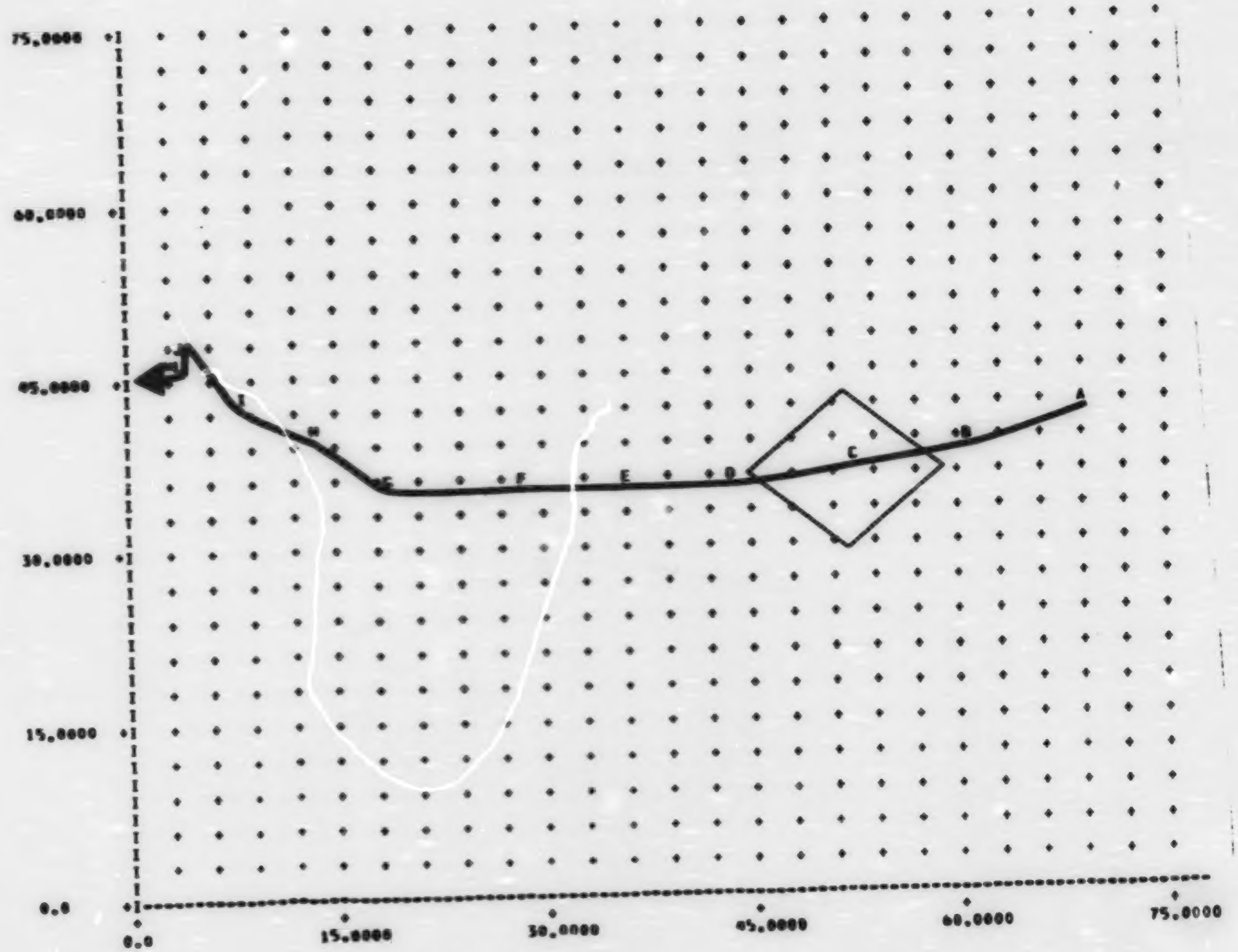
1 June 1976



2 June 1976



3 June 1976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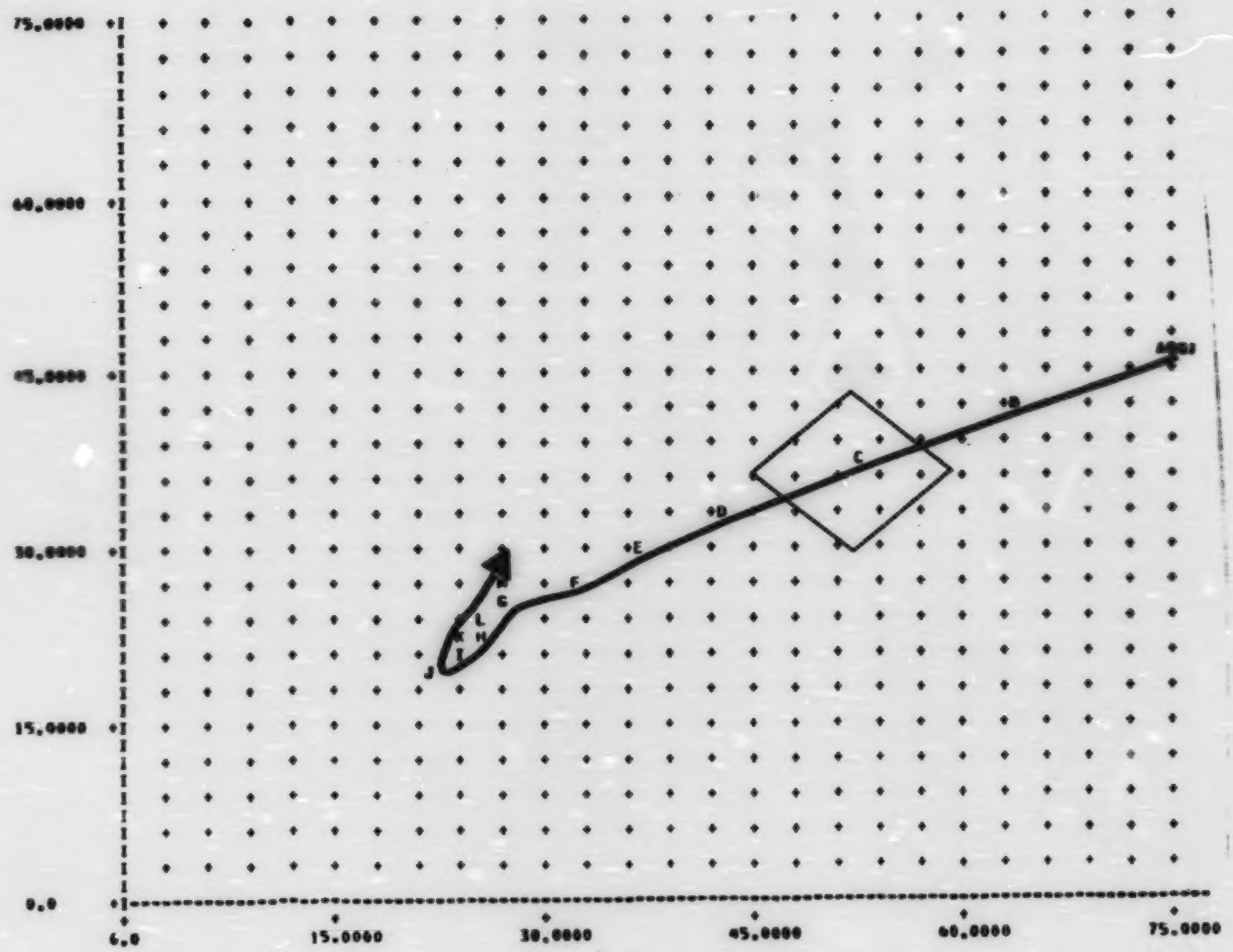
4 June 1976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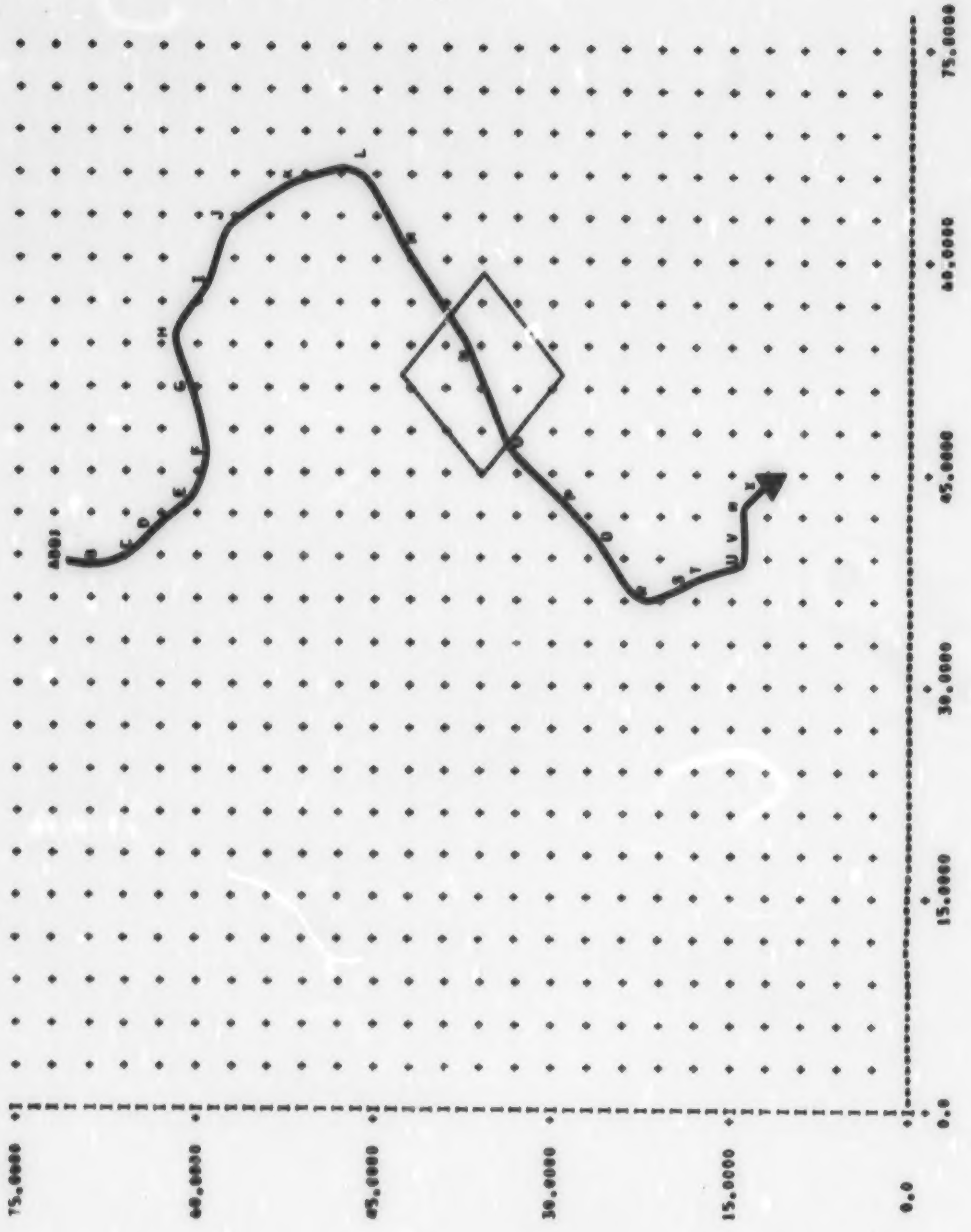
5 June 1976



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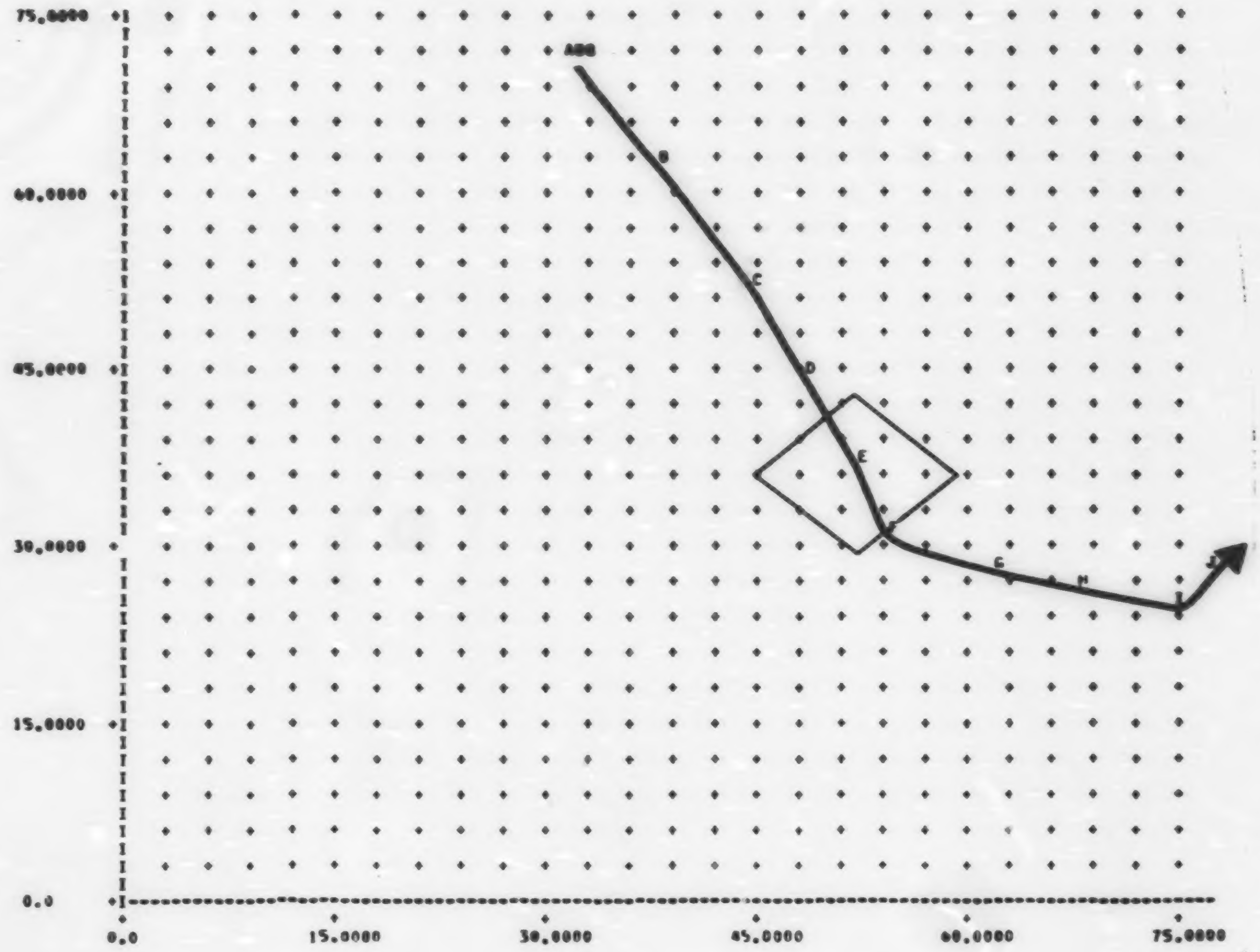
6 June 1976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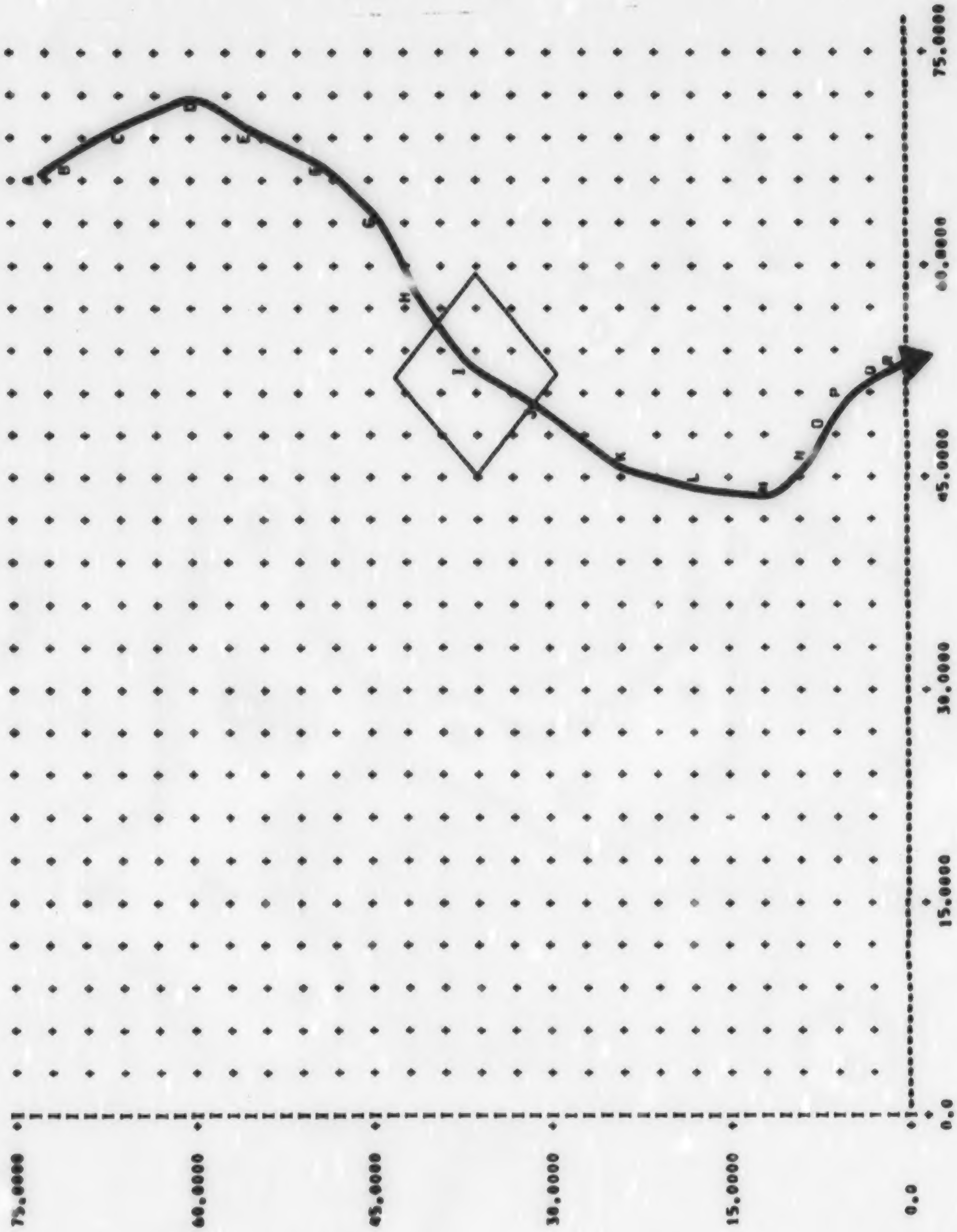
7 June 1976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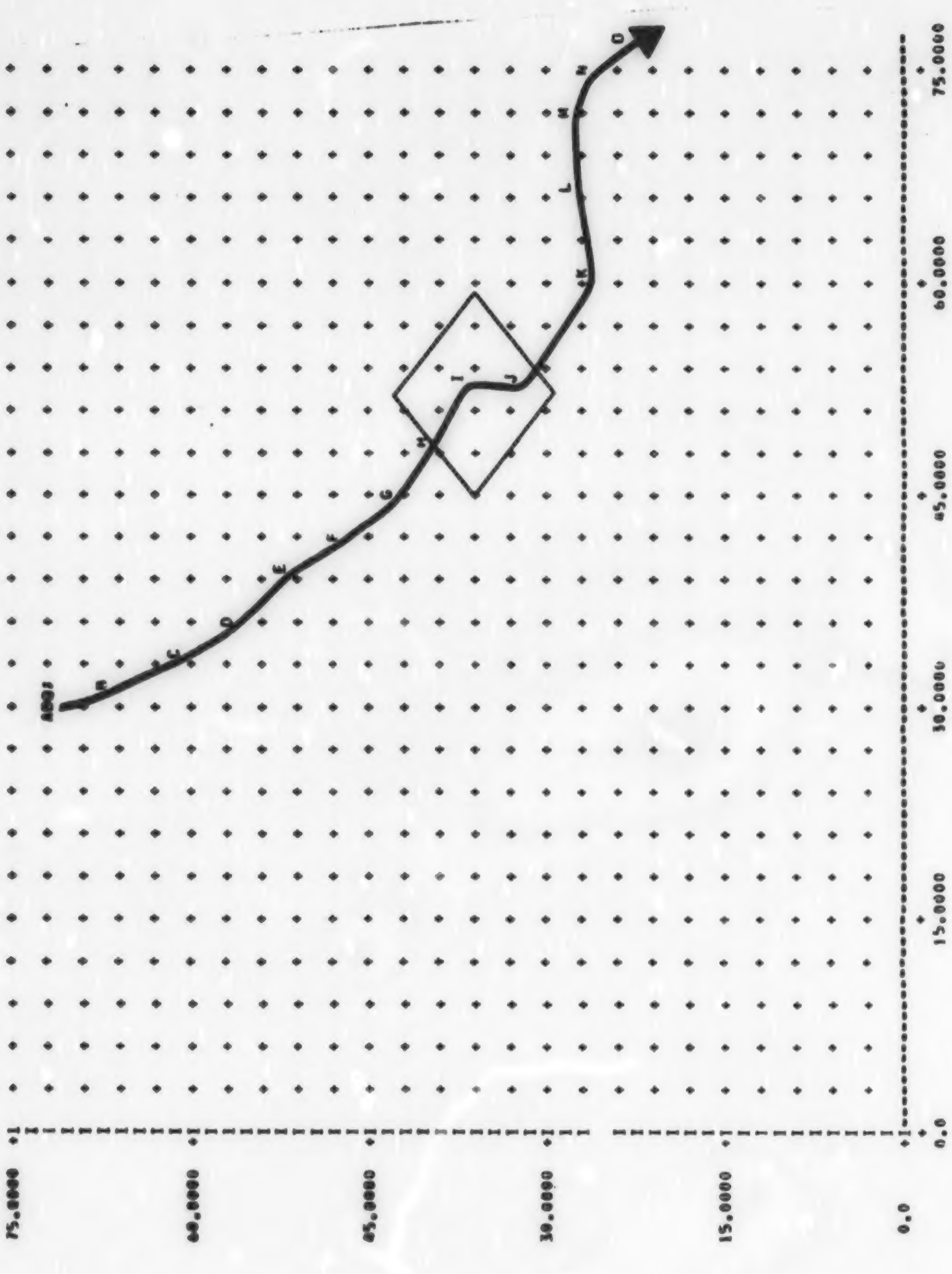
8 June 1976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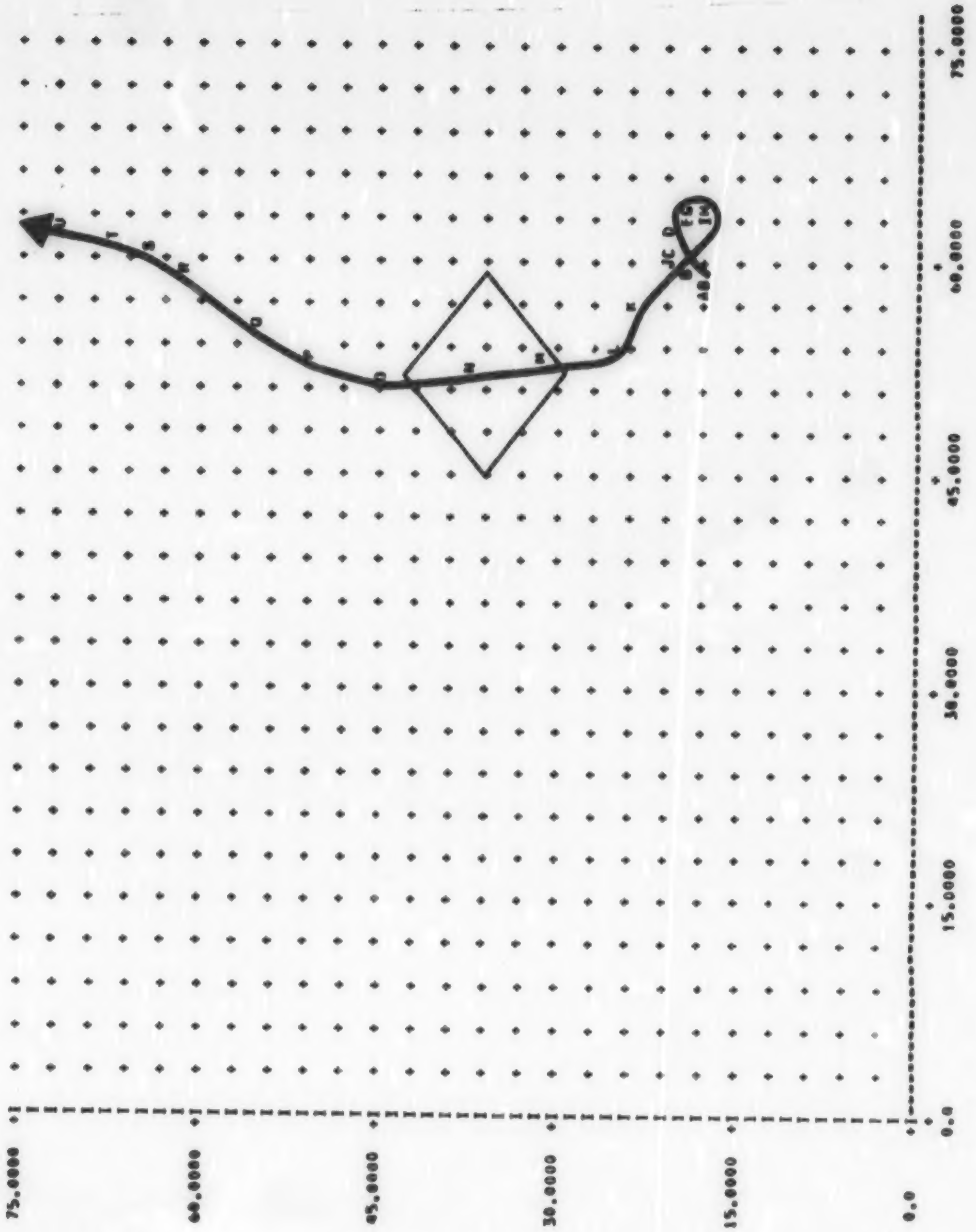
9 June 1976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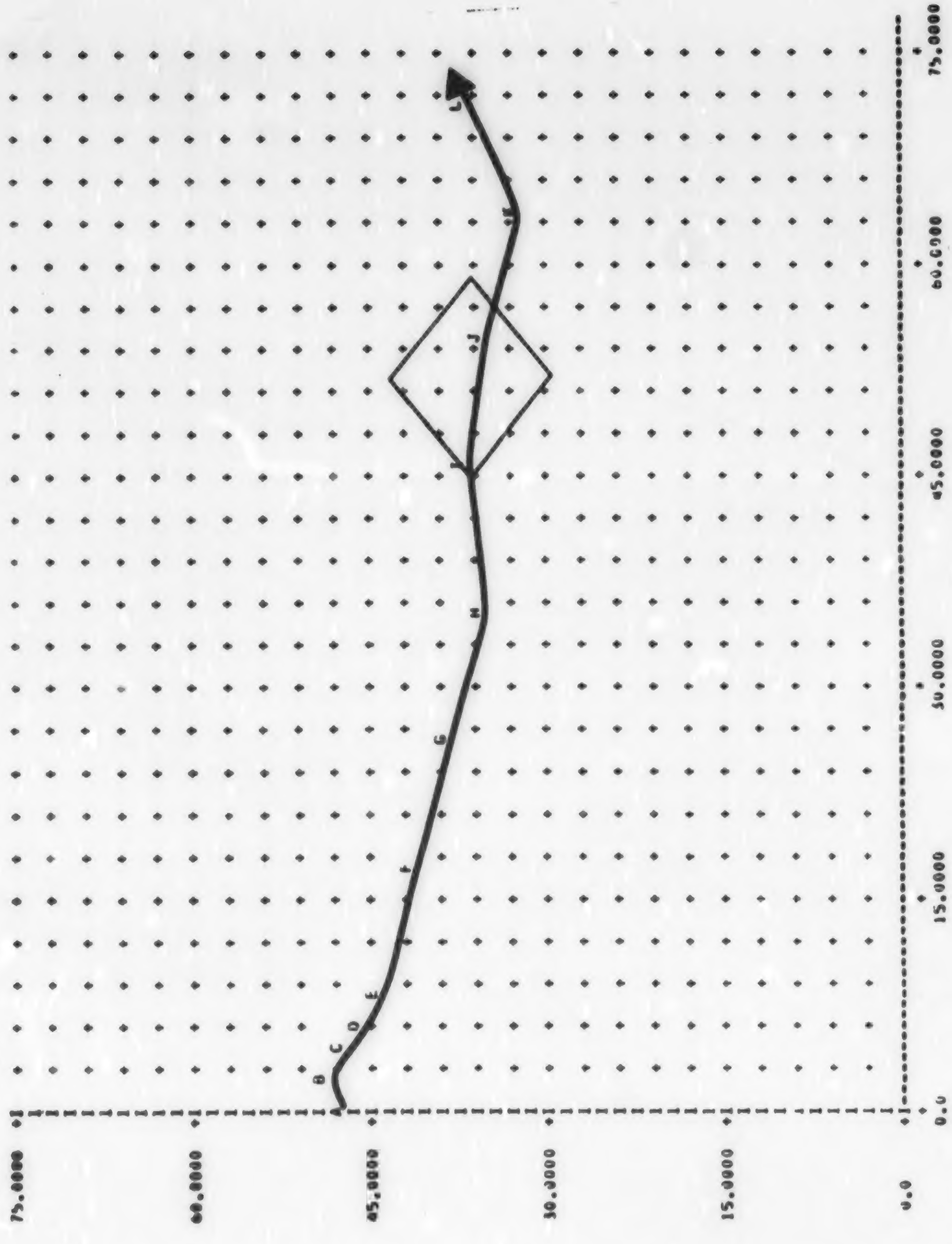
10 June 1976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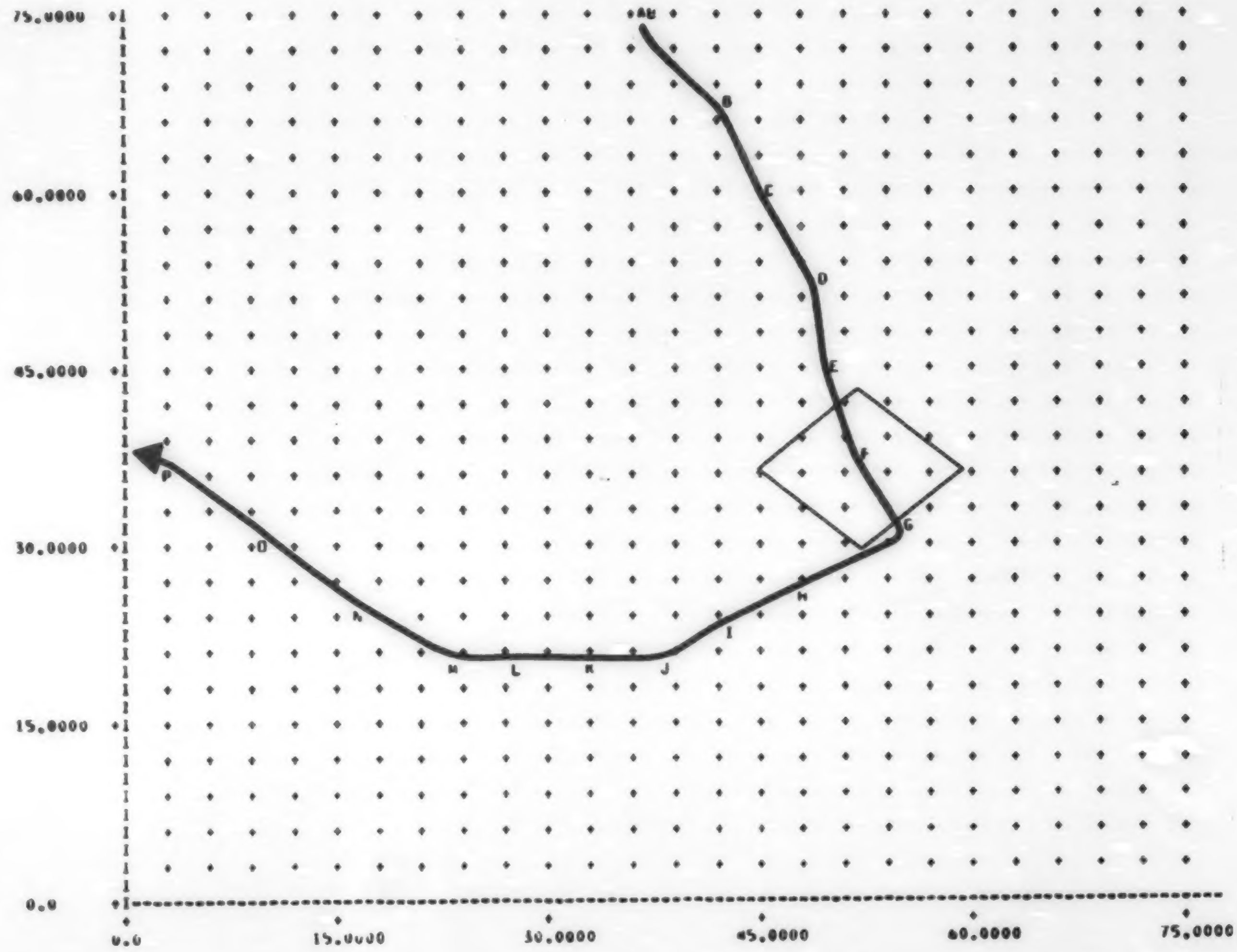
11 June 1976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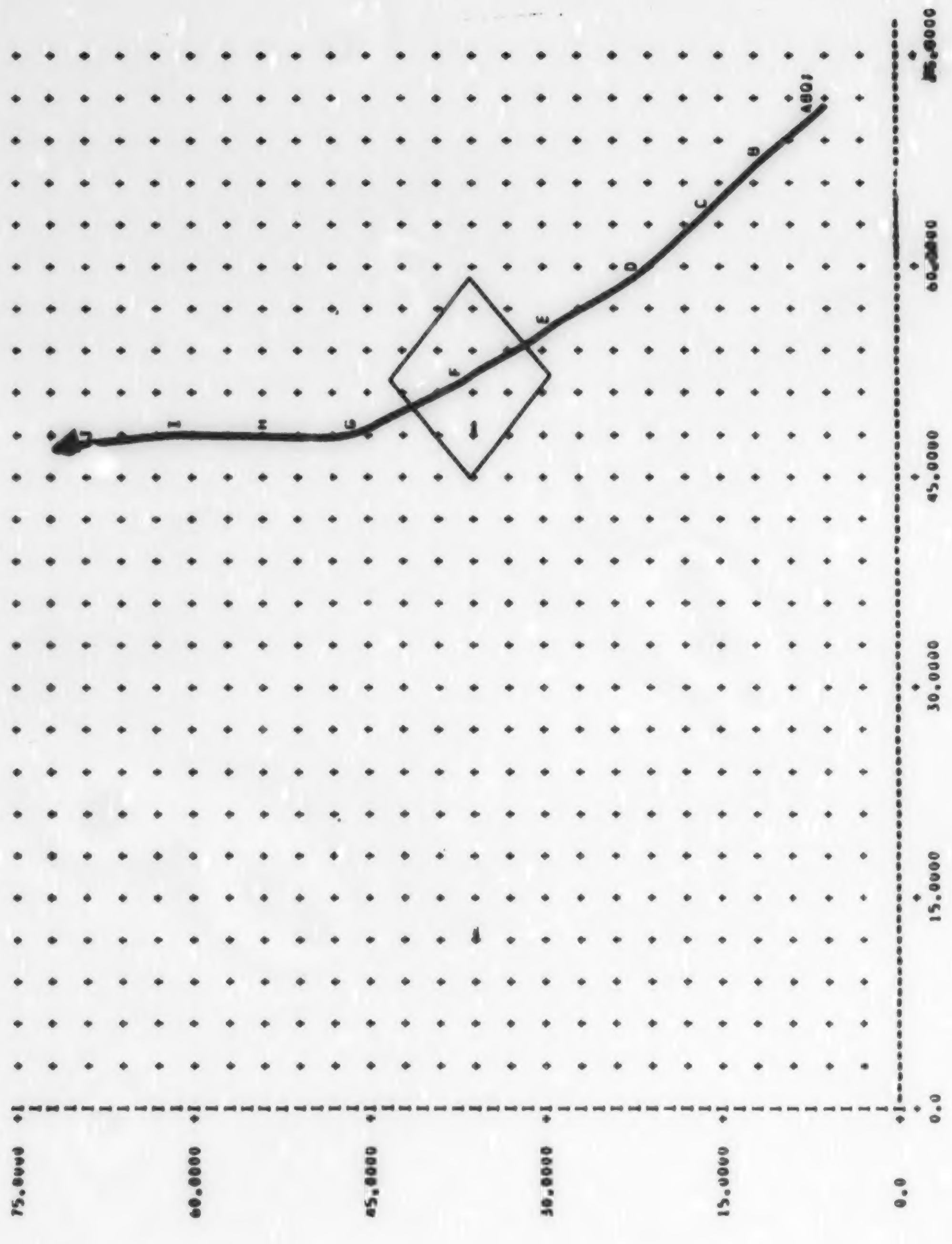
12 June 1976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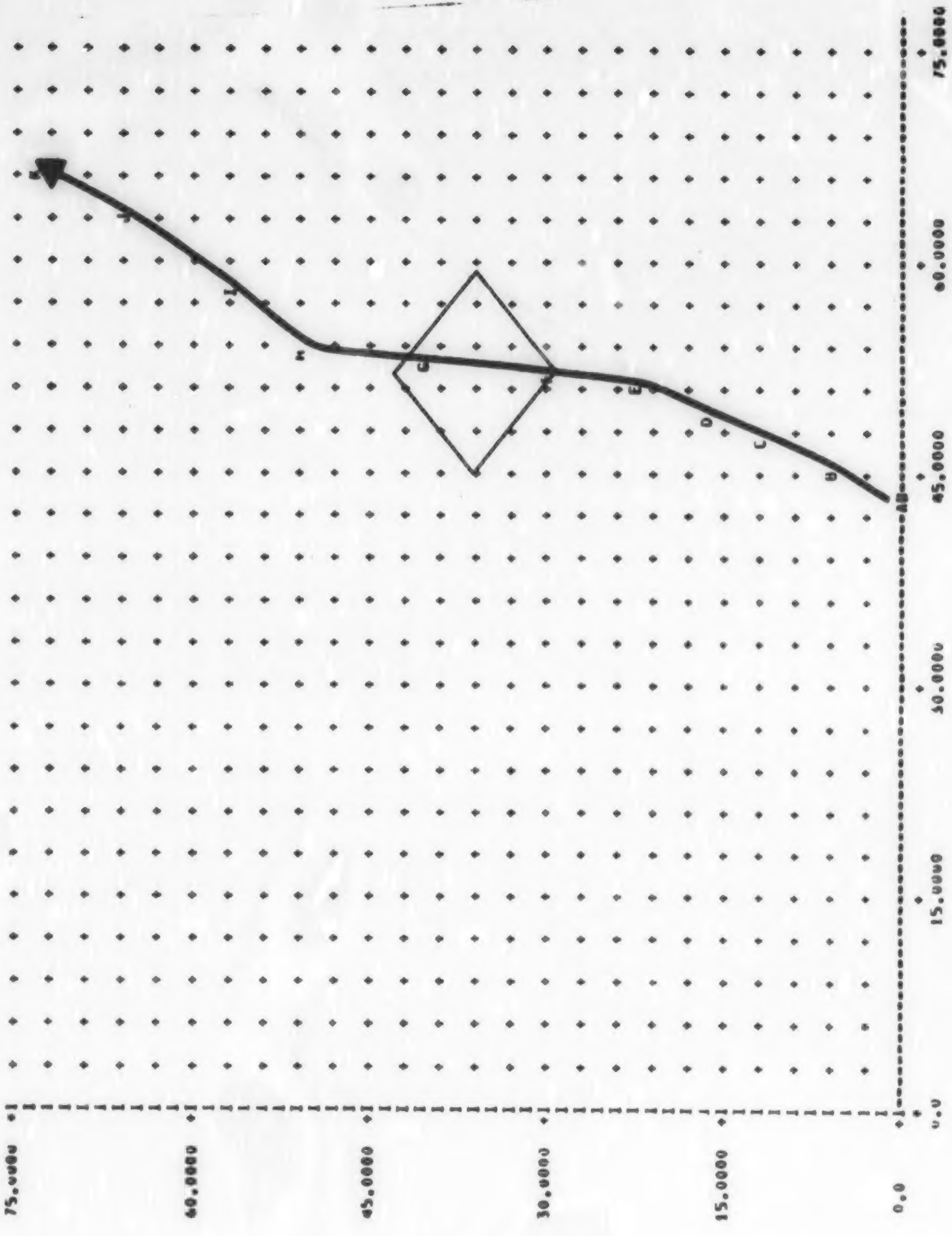
13 June 1976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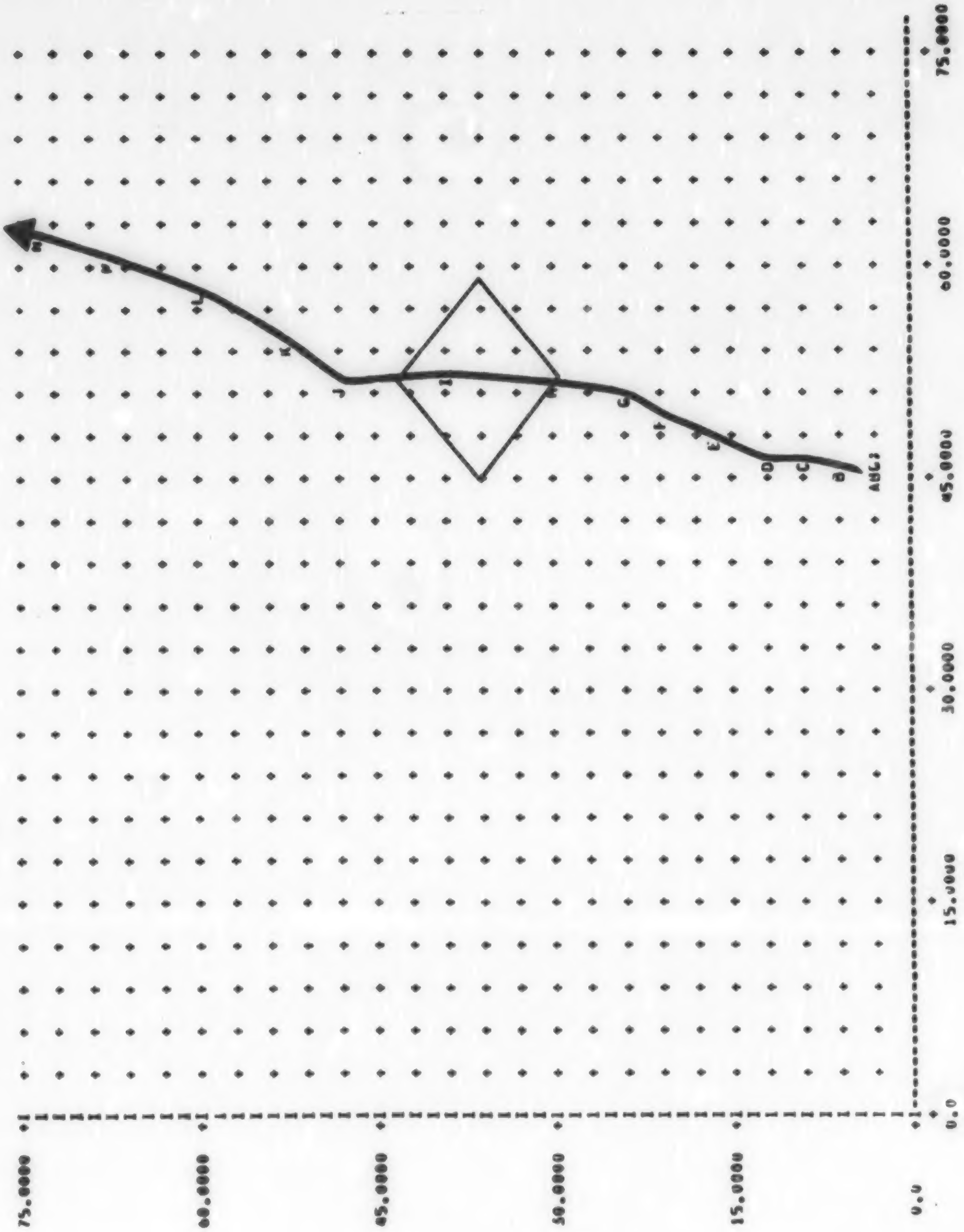
14 June 1976



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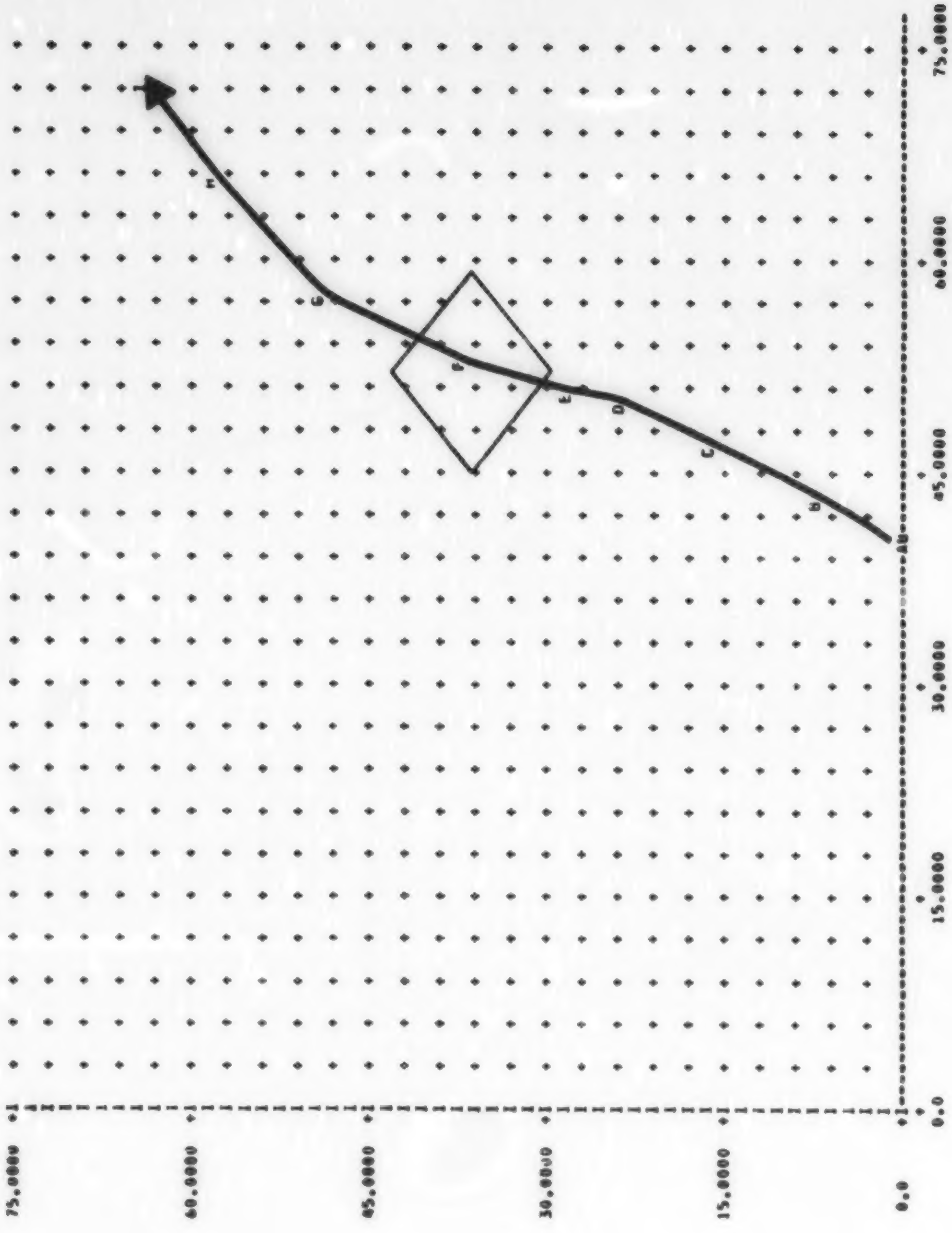
15 June 1976



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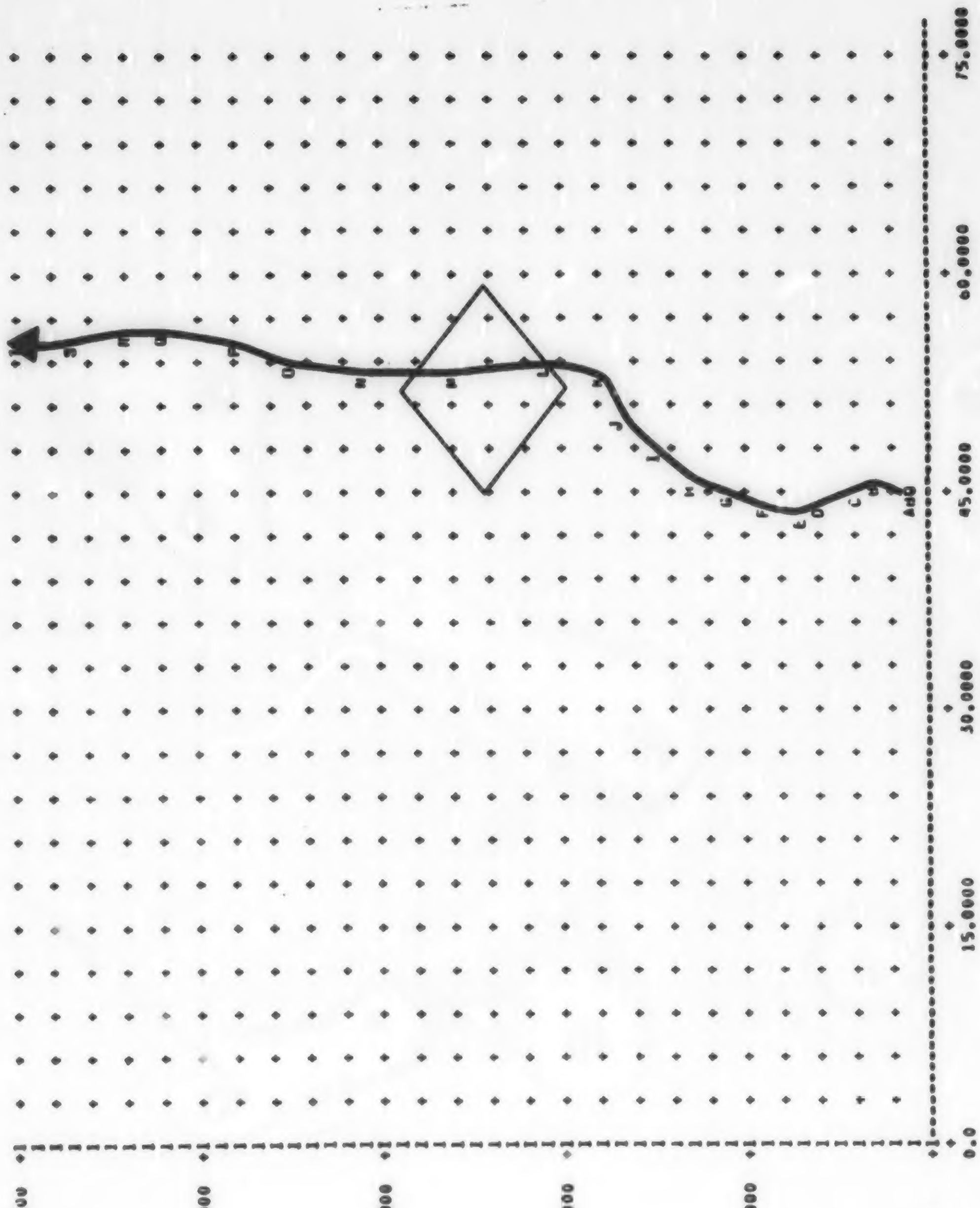
16 June 1976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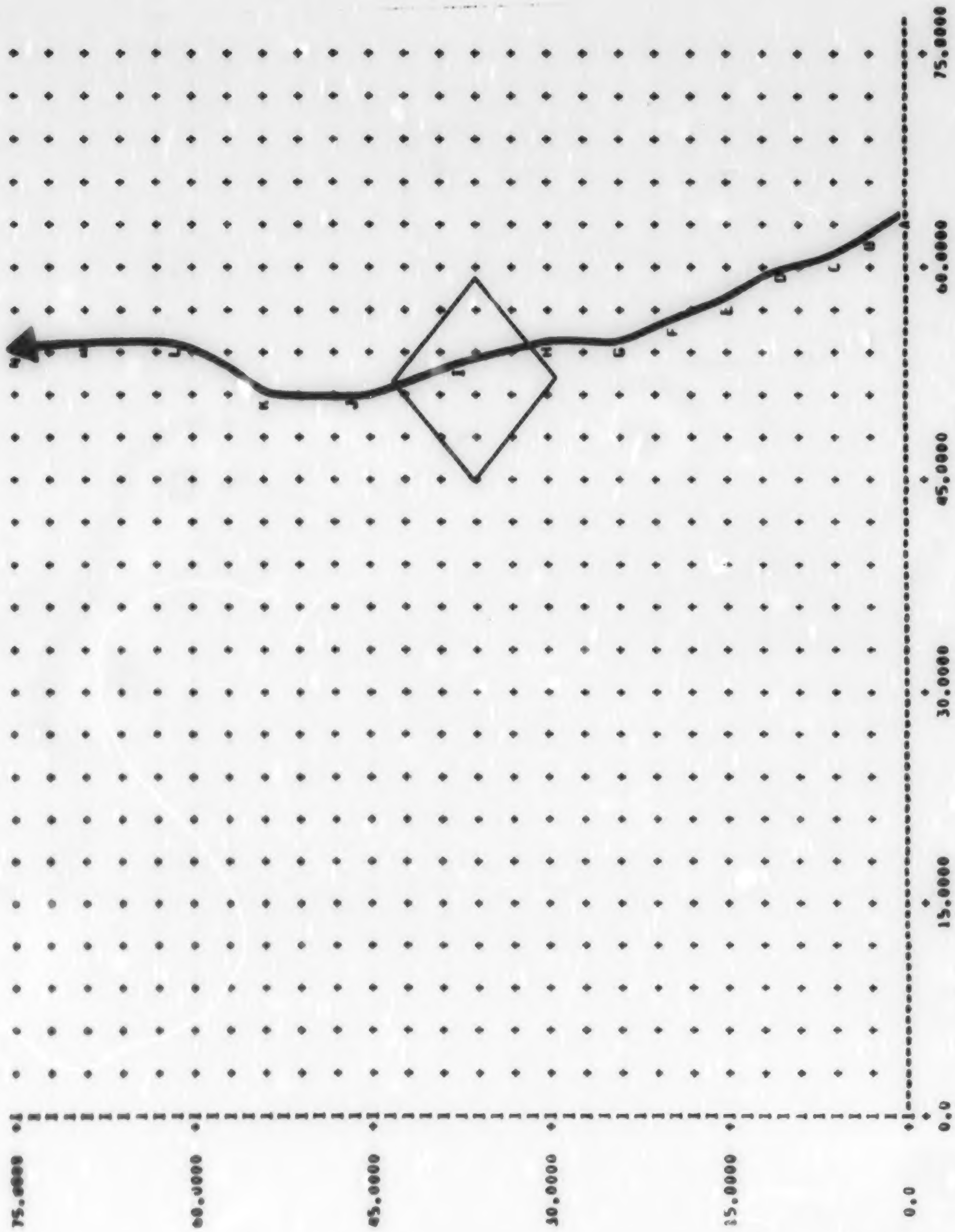
17 June 1976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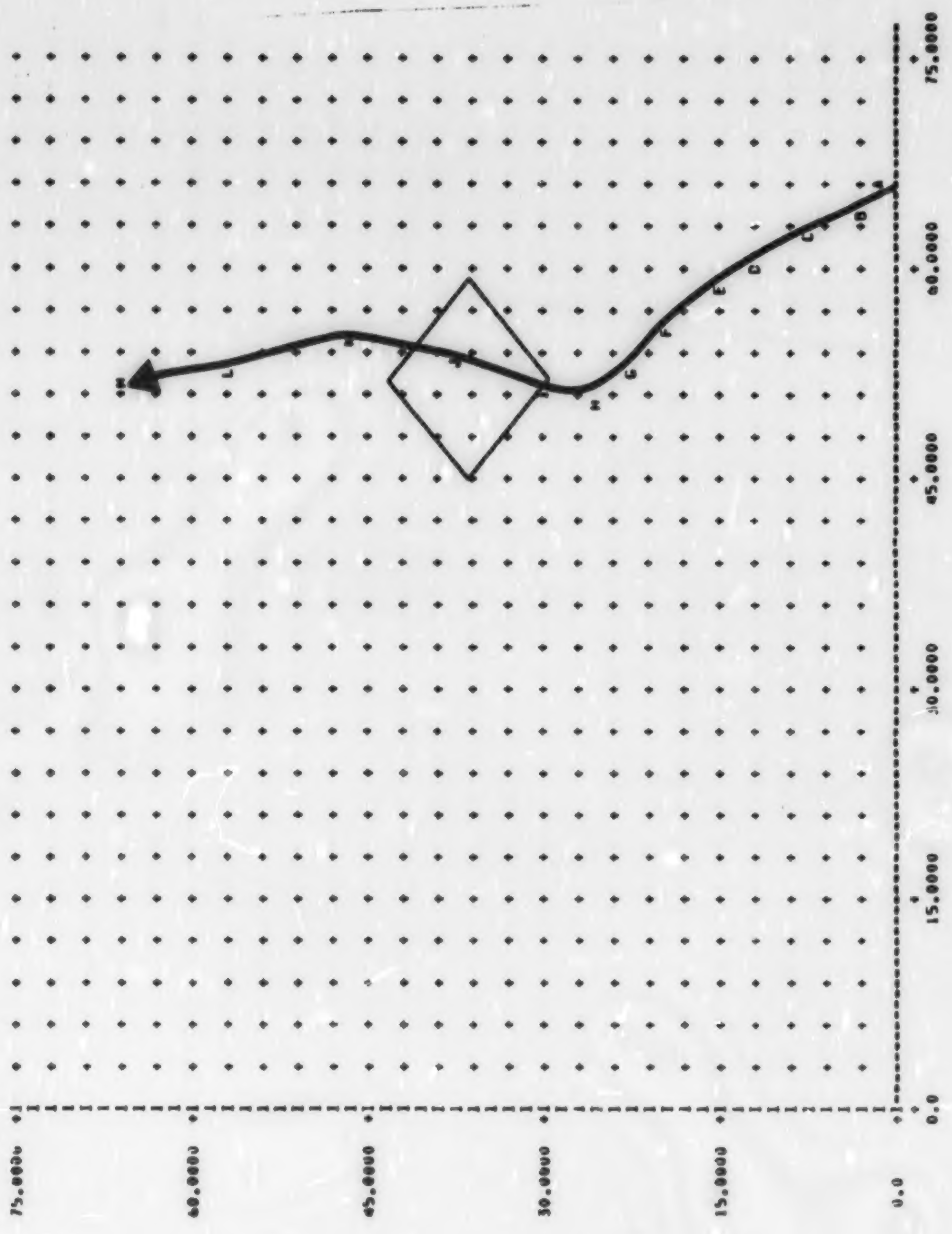
18 June 1976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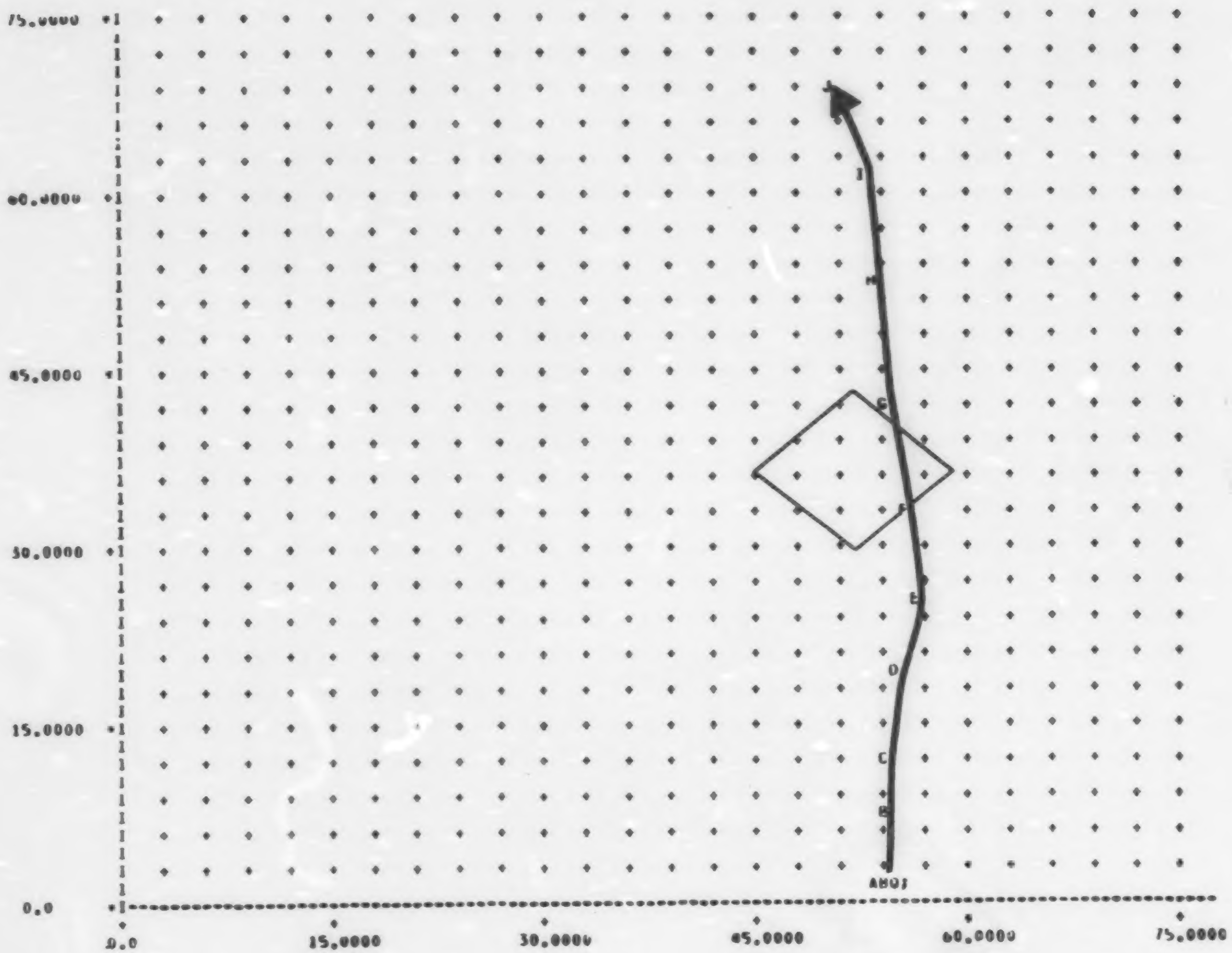
19 June 1976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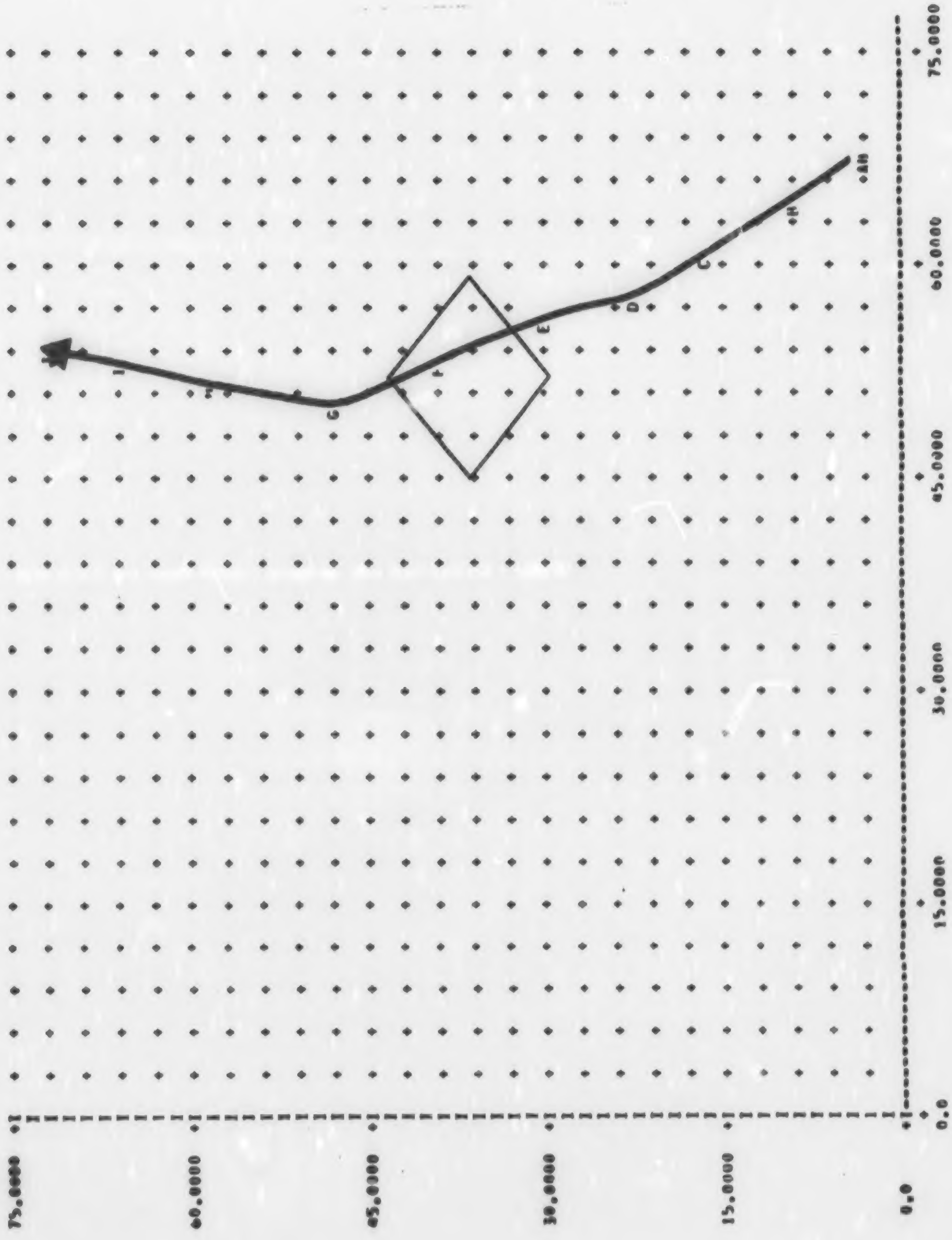
20 June 1976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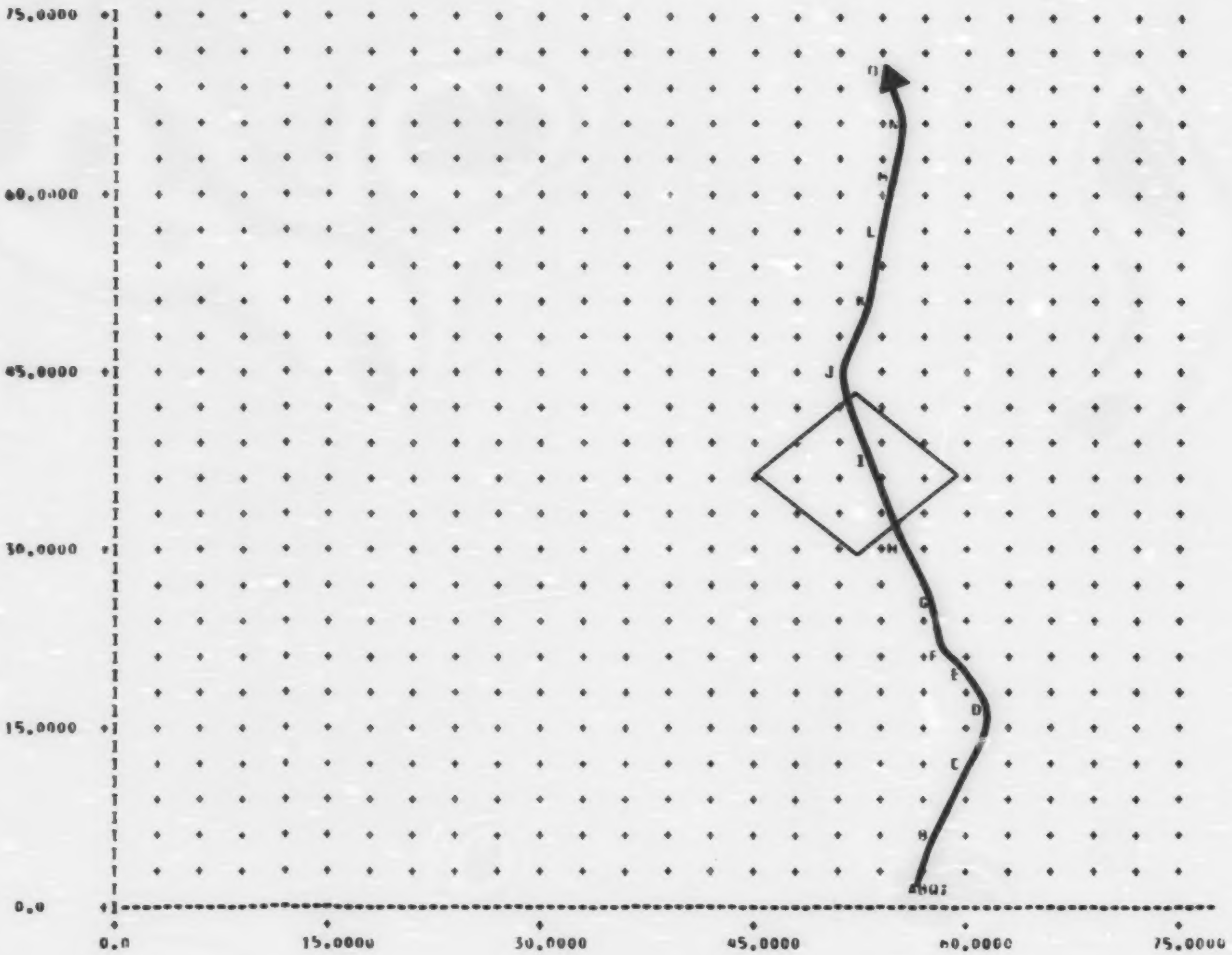
21 June 1976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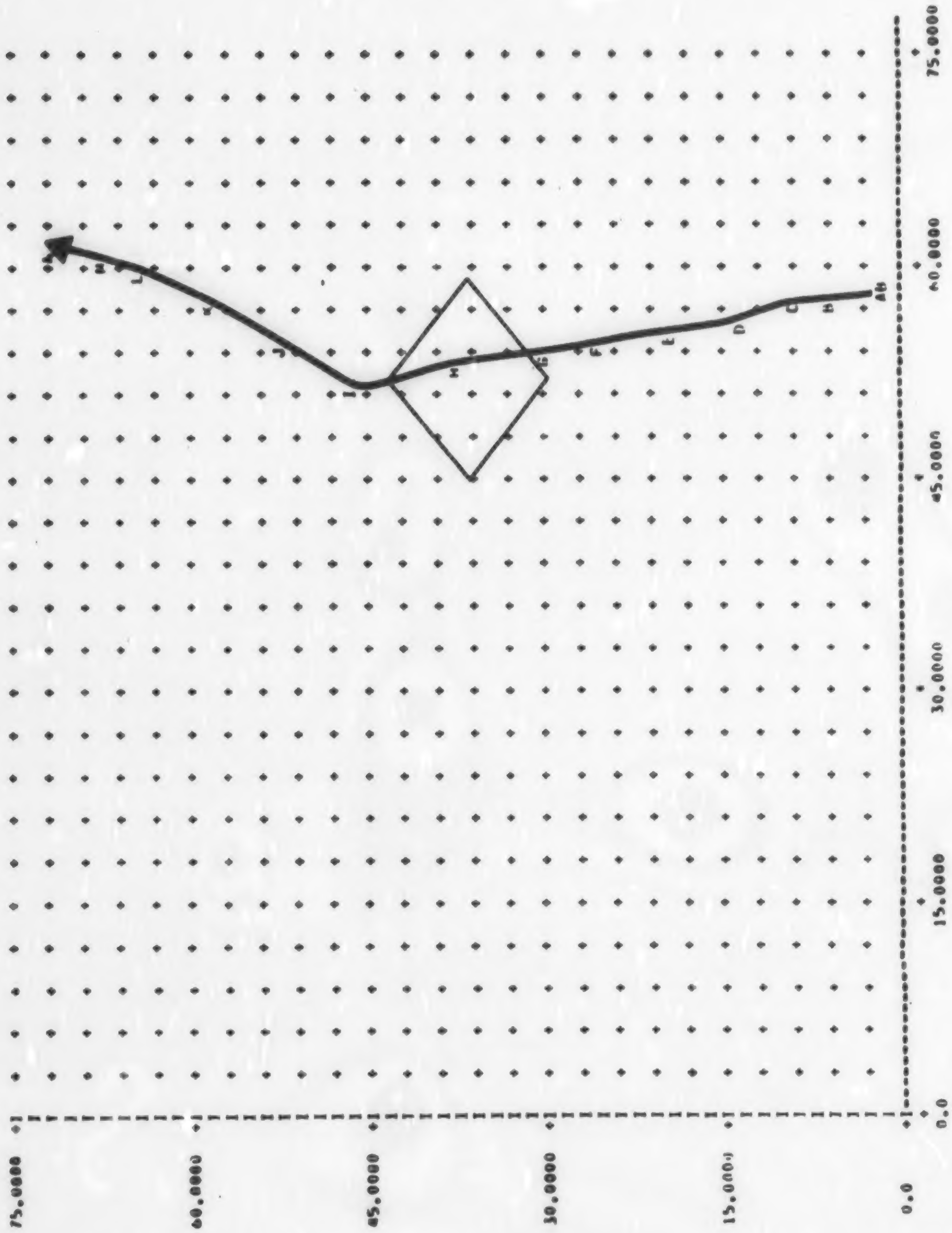
22 June 1976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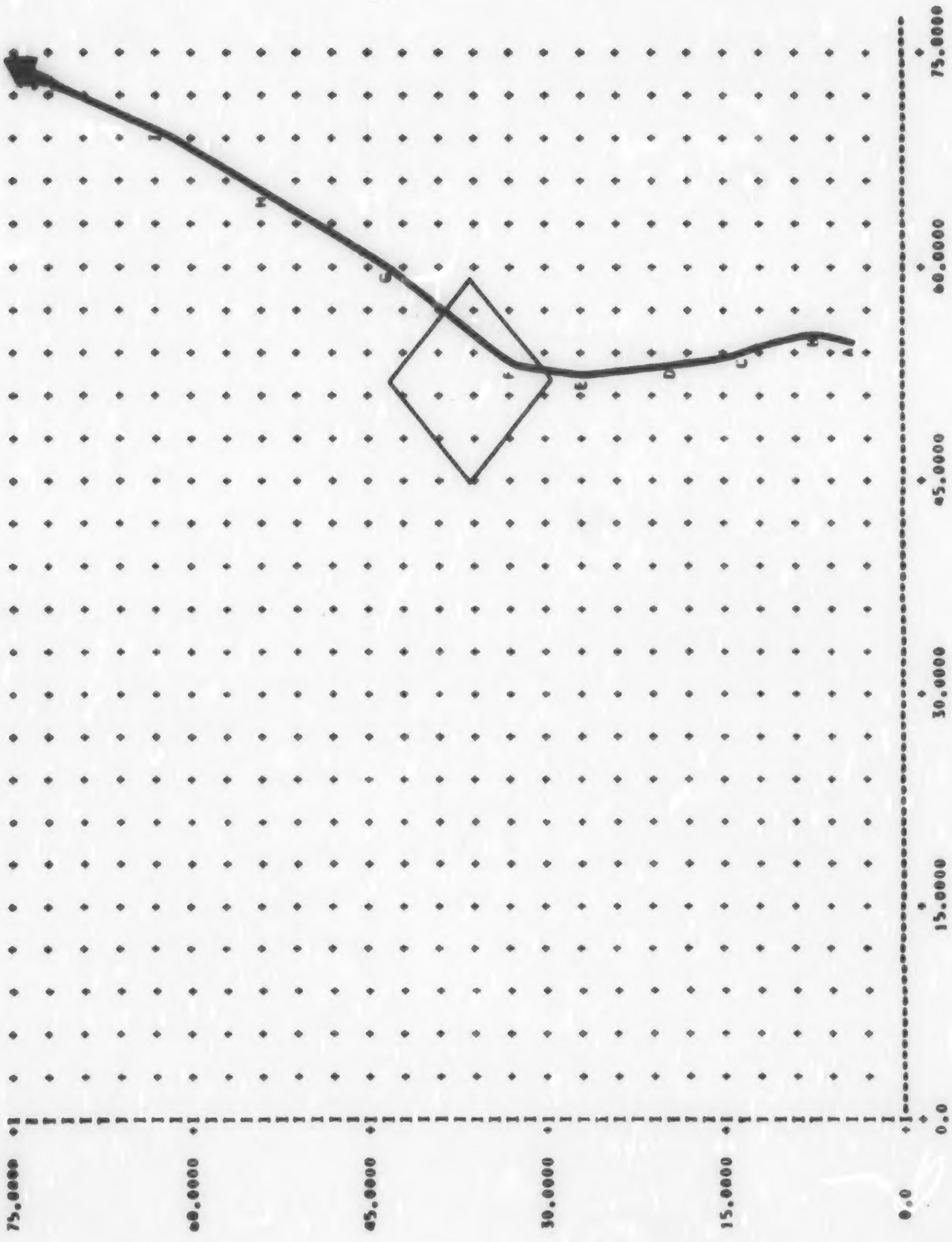
23 June 1976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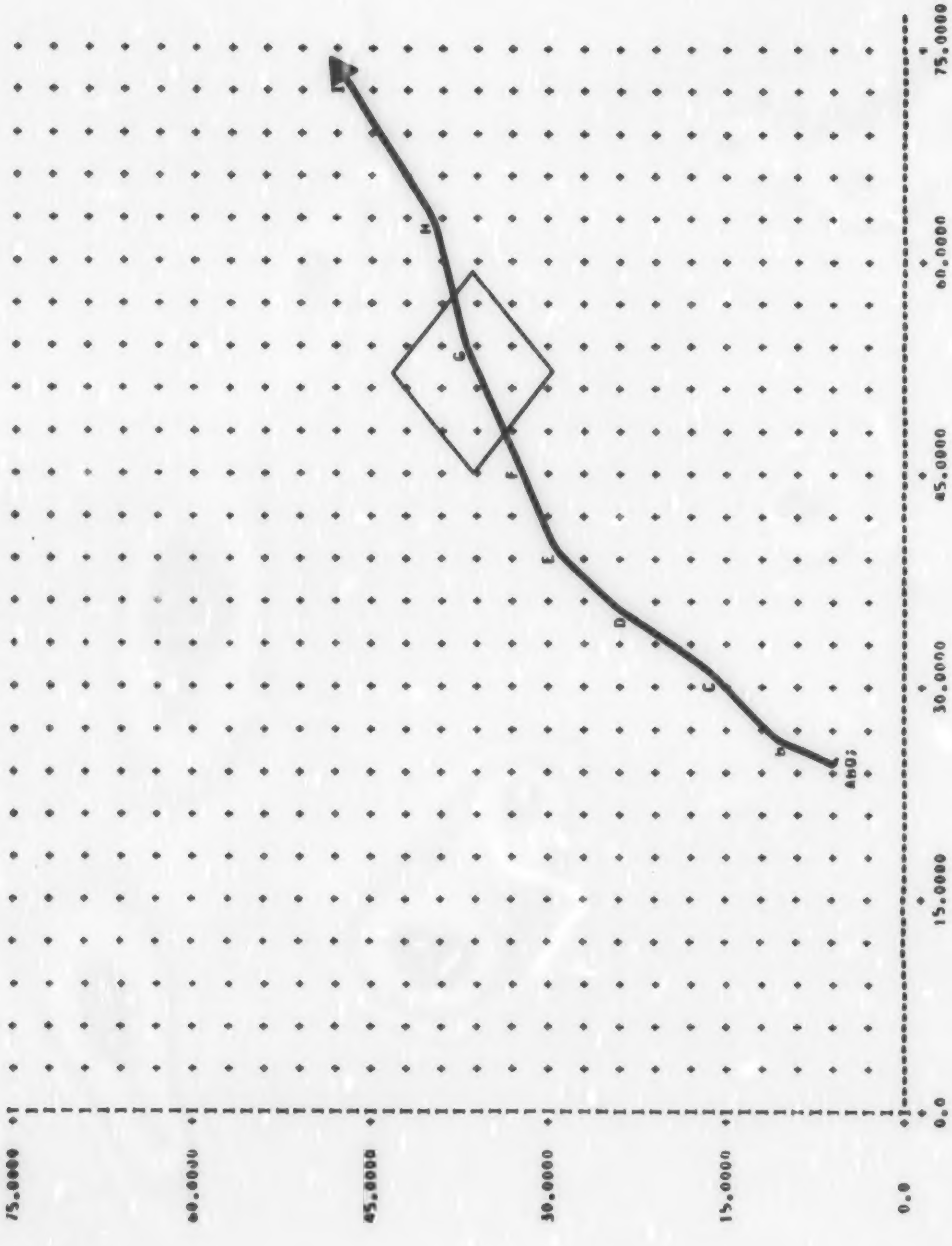
24 June 1976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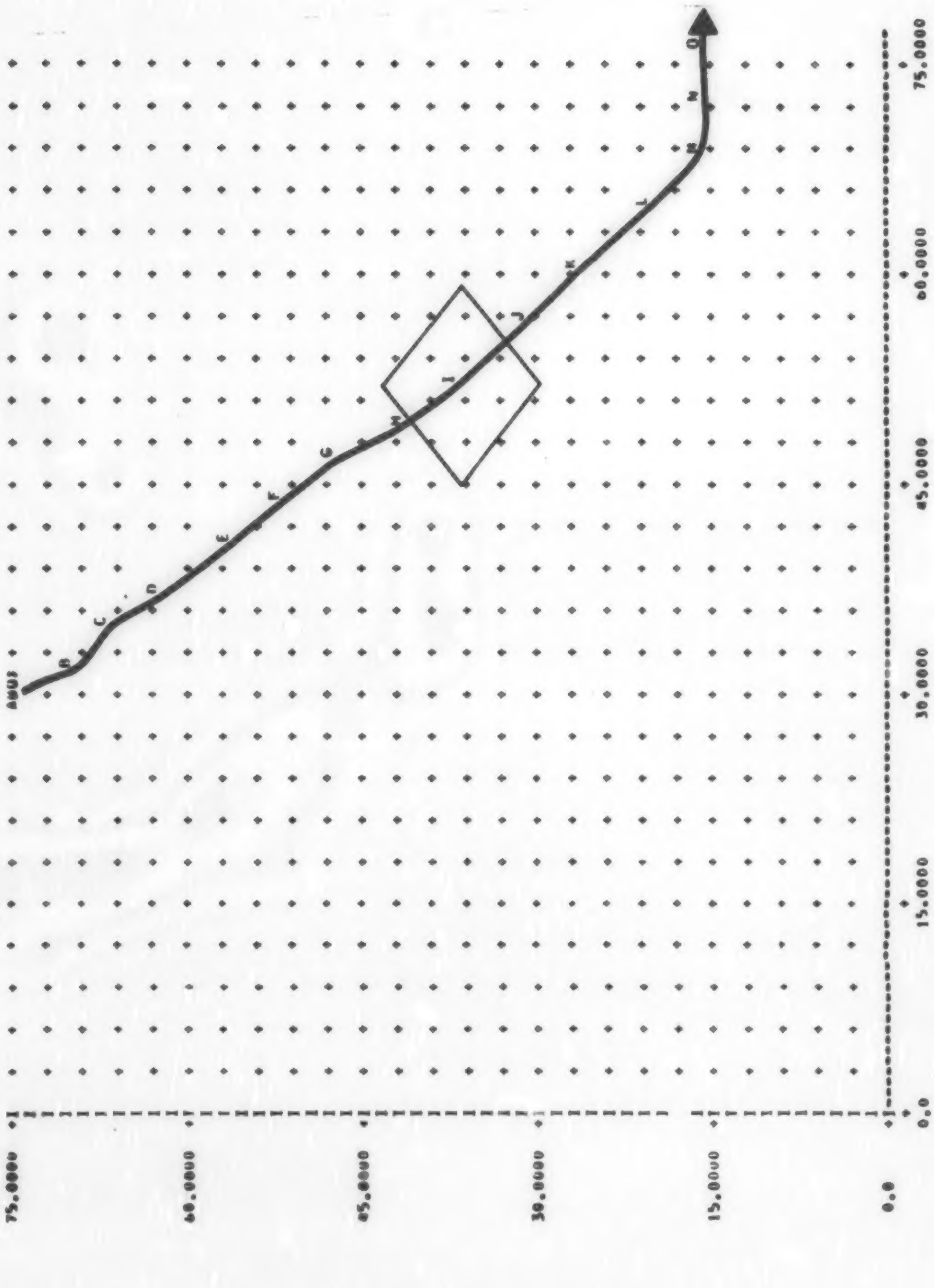
25 June 1976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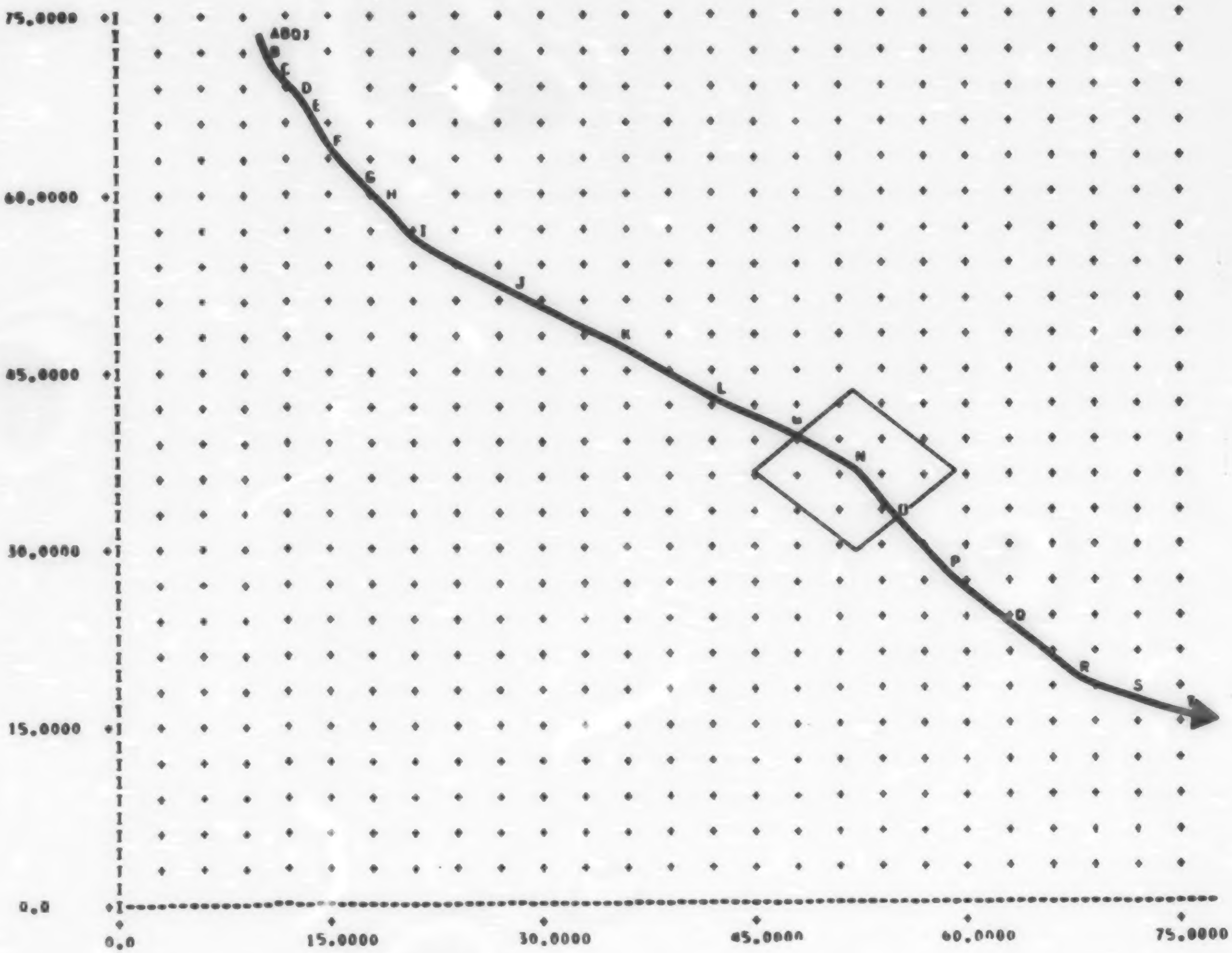
26 June 1976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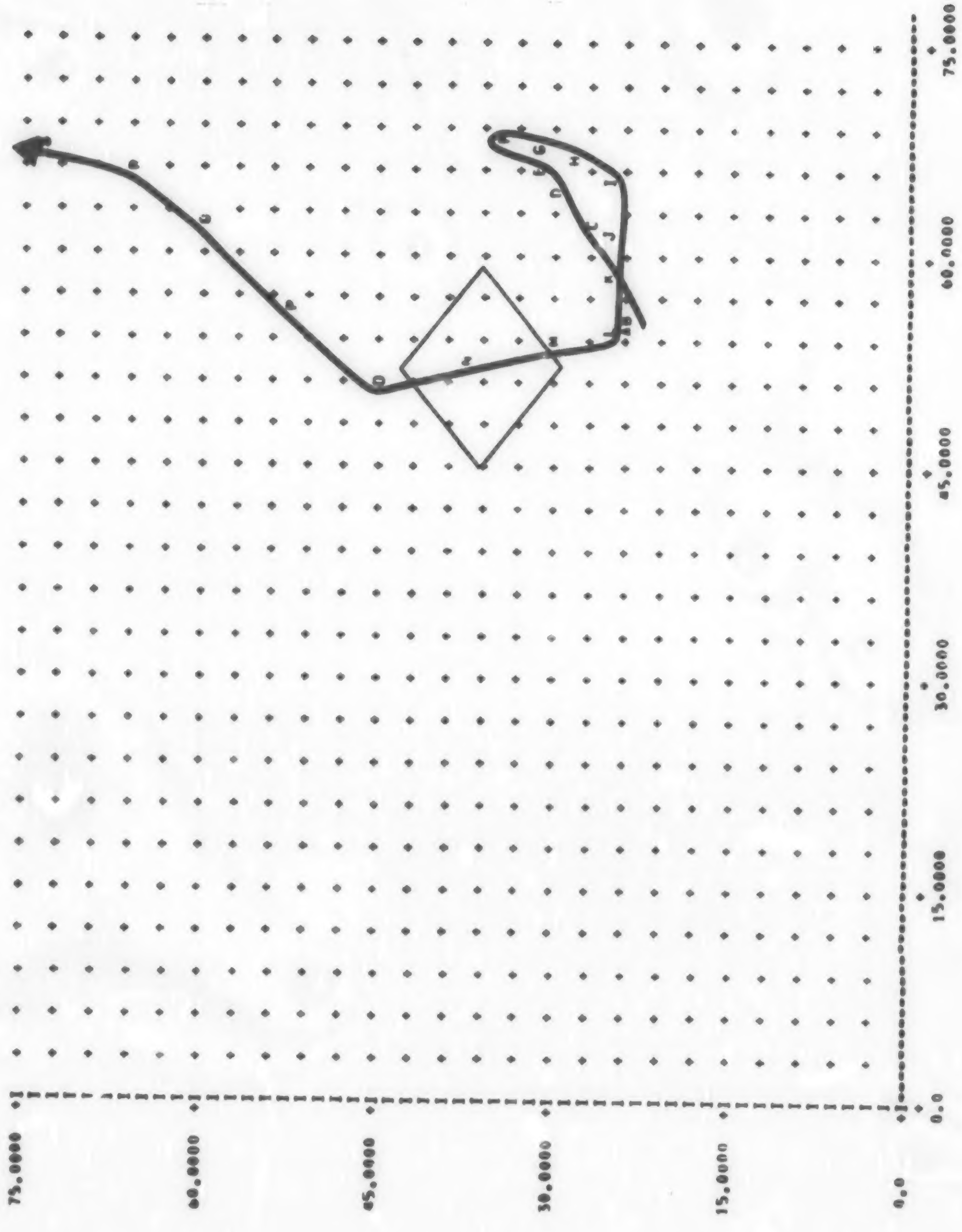
27 June 1976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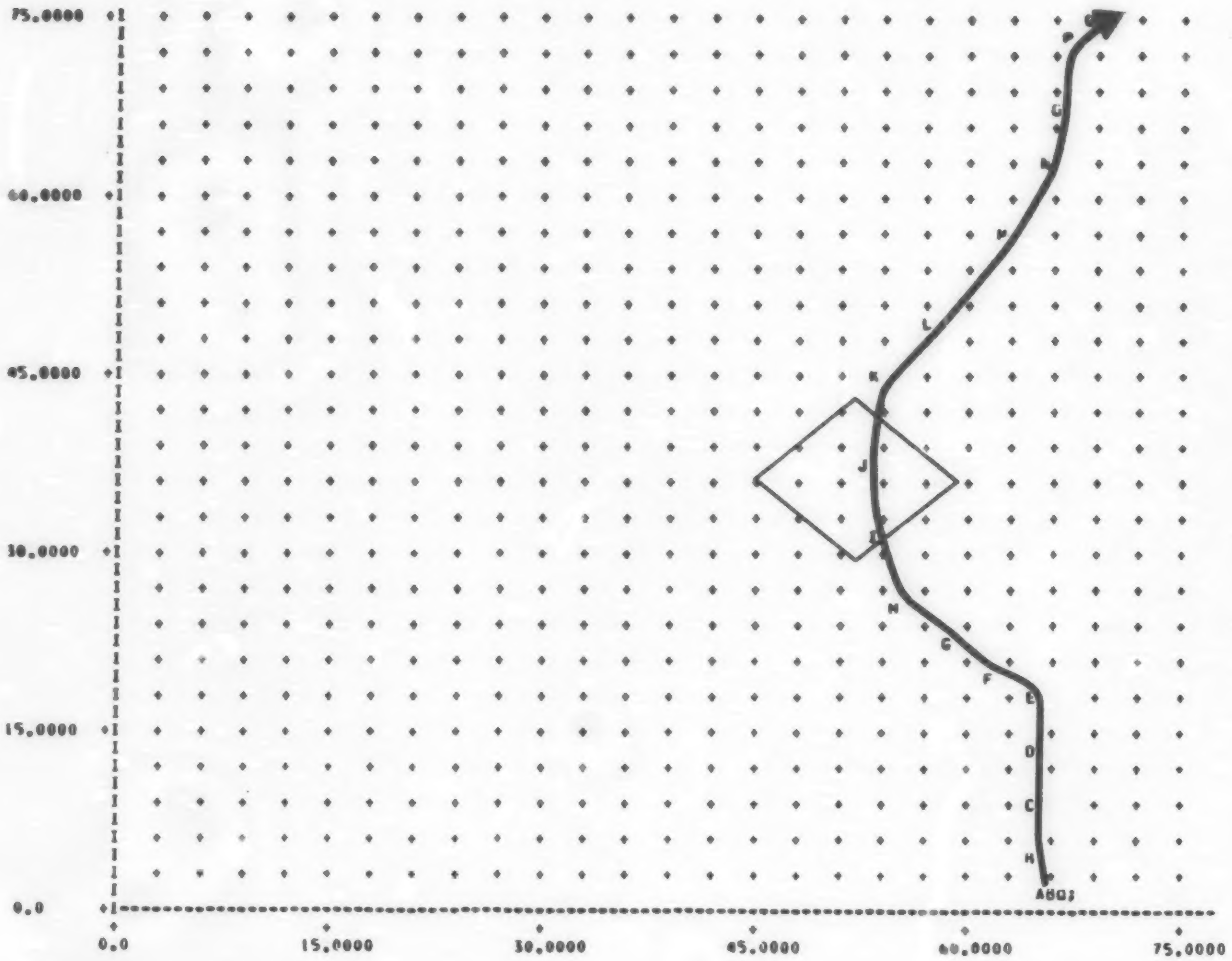
28 June 1976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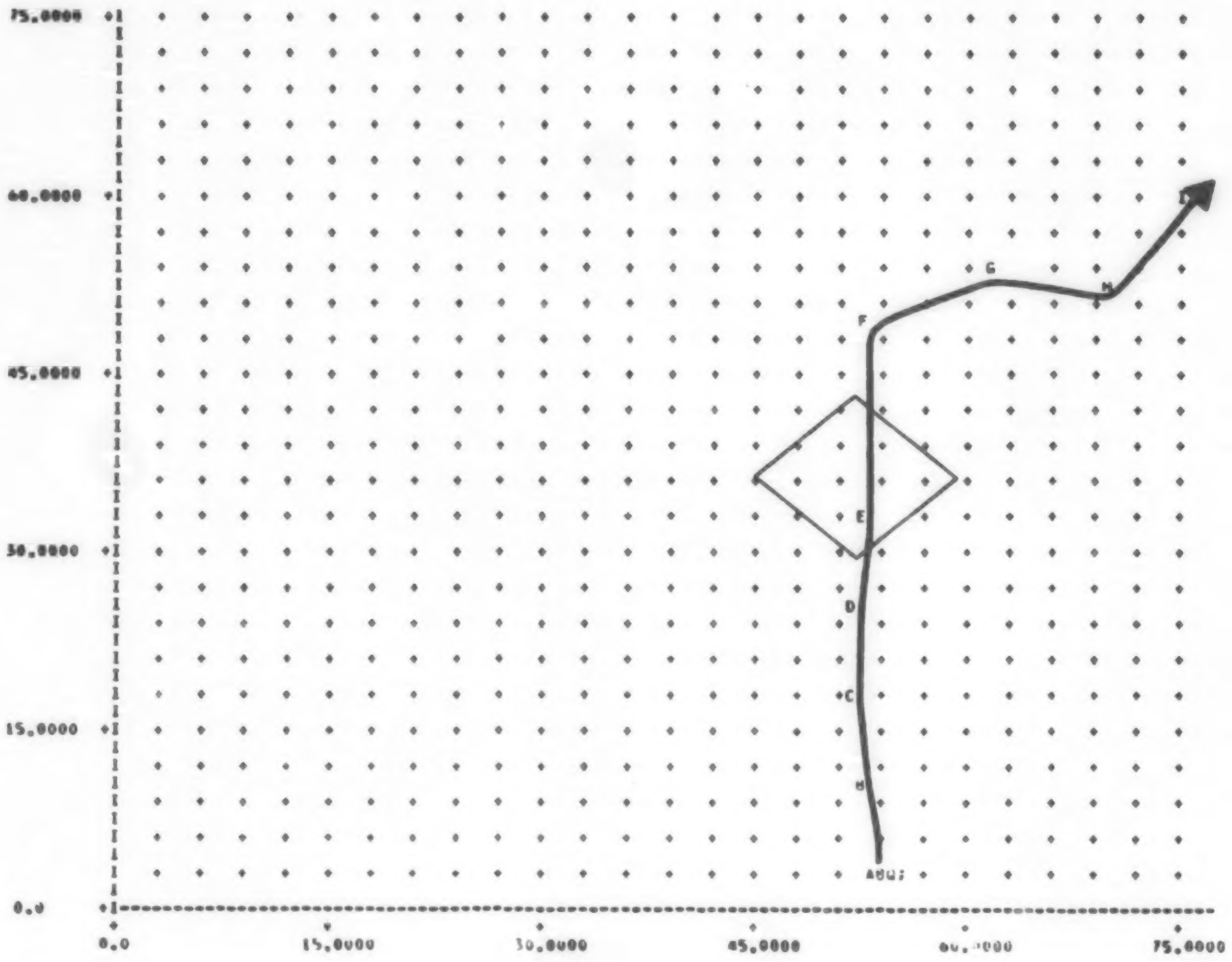
29 June 1976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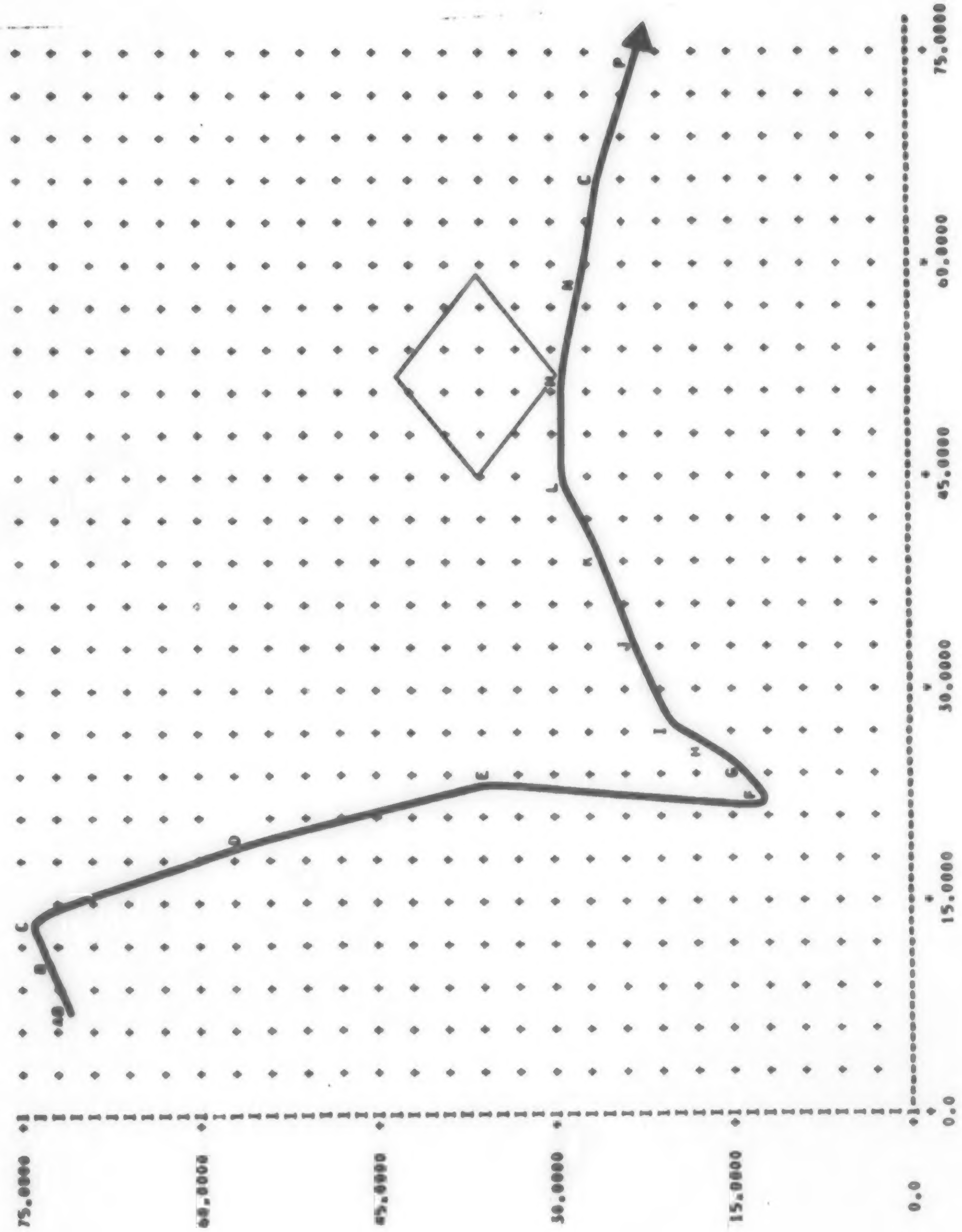
30 June 1976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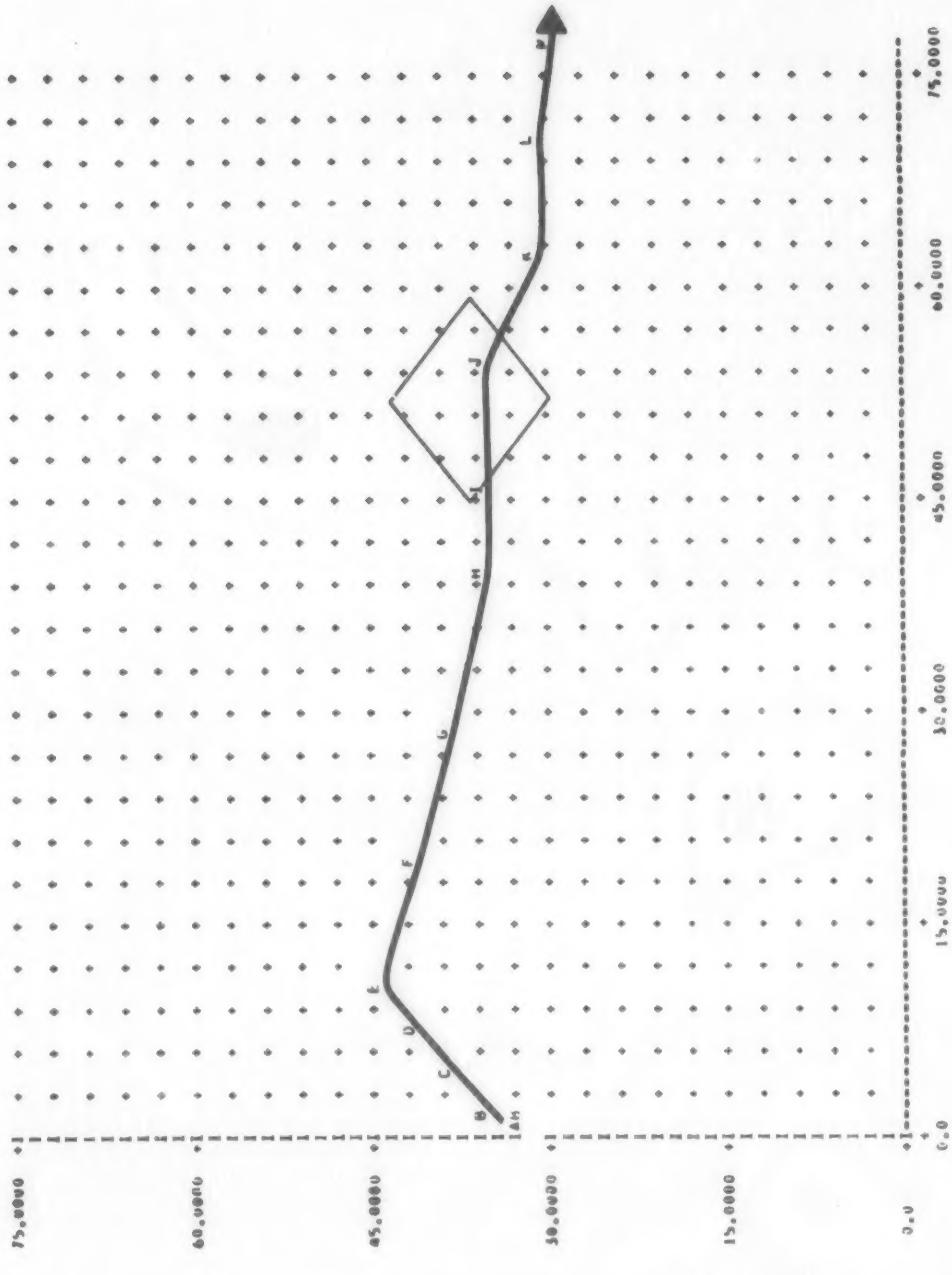
1 July 1976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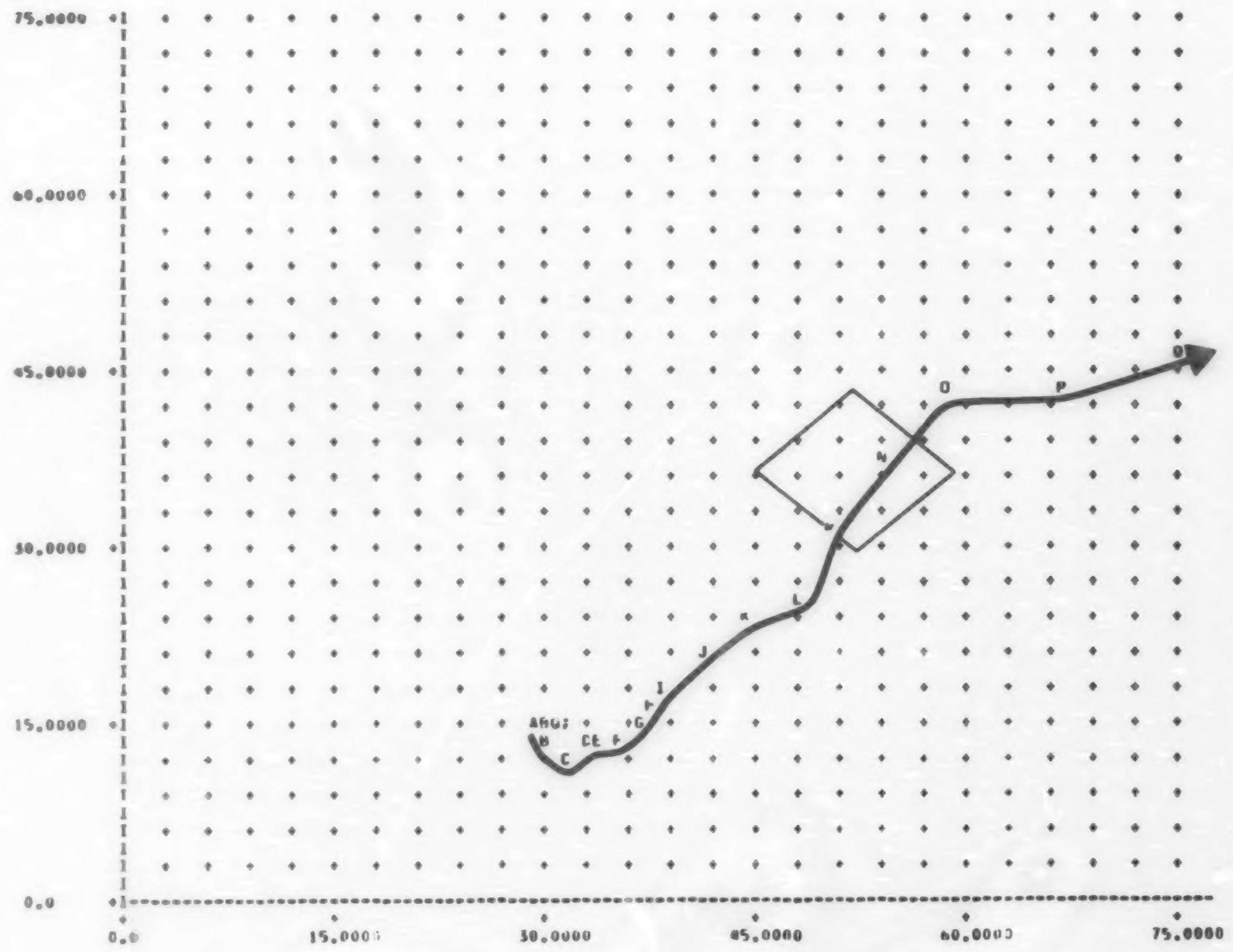
2 July 1976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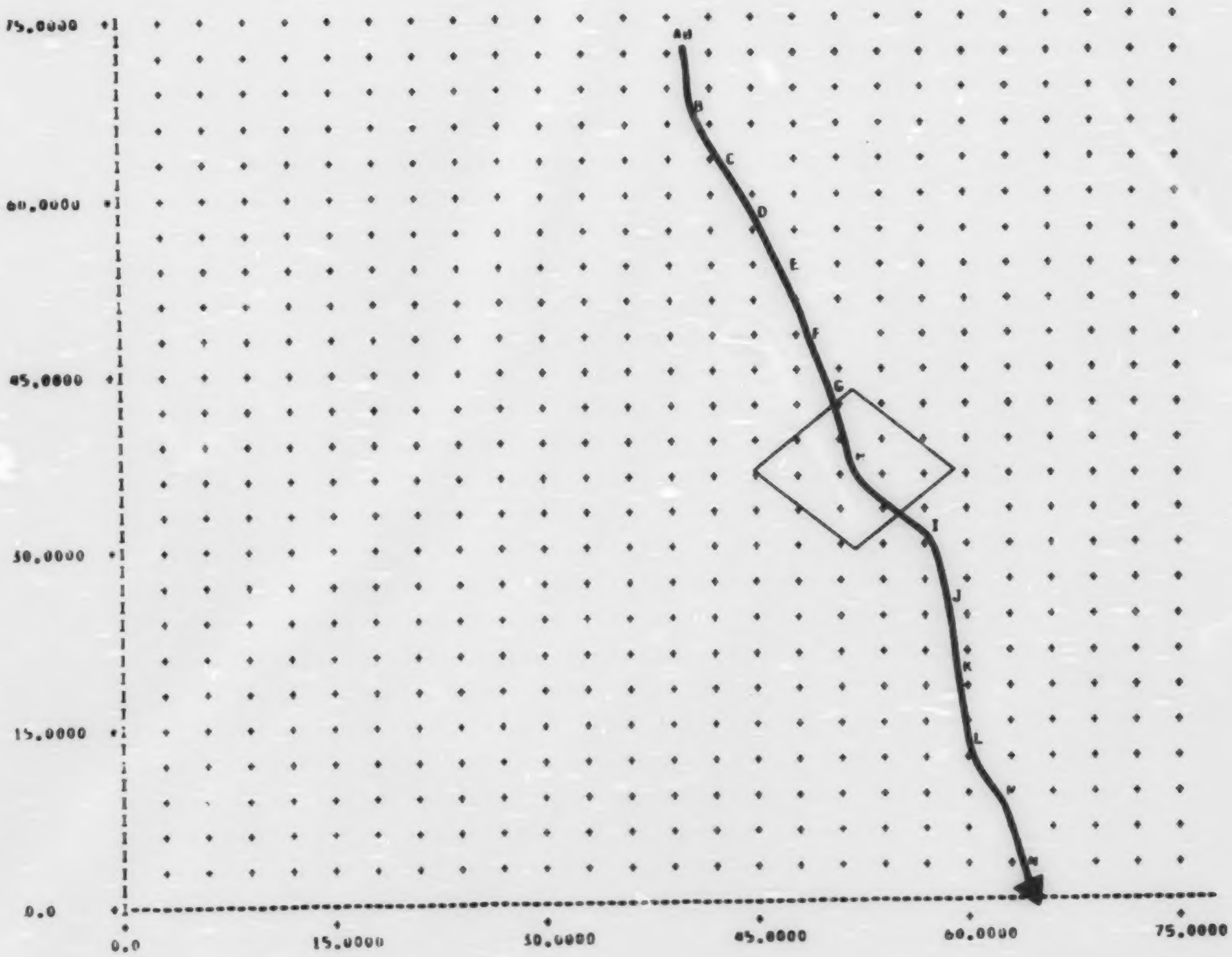
3 July 1976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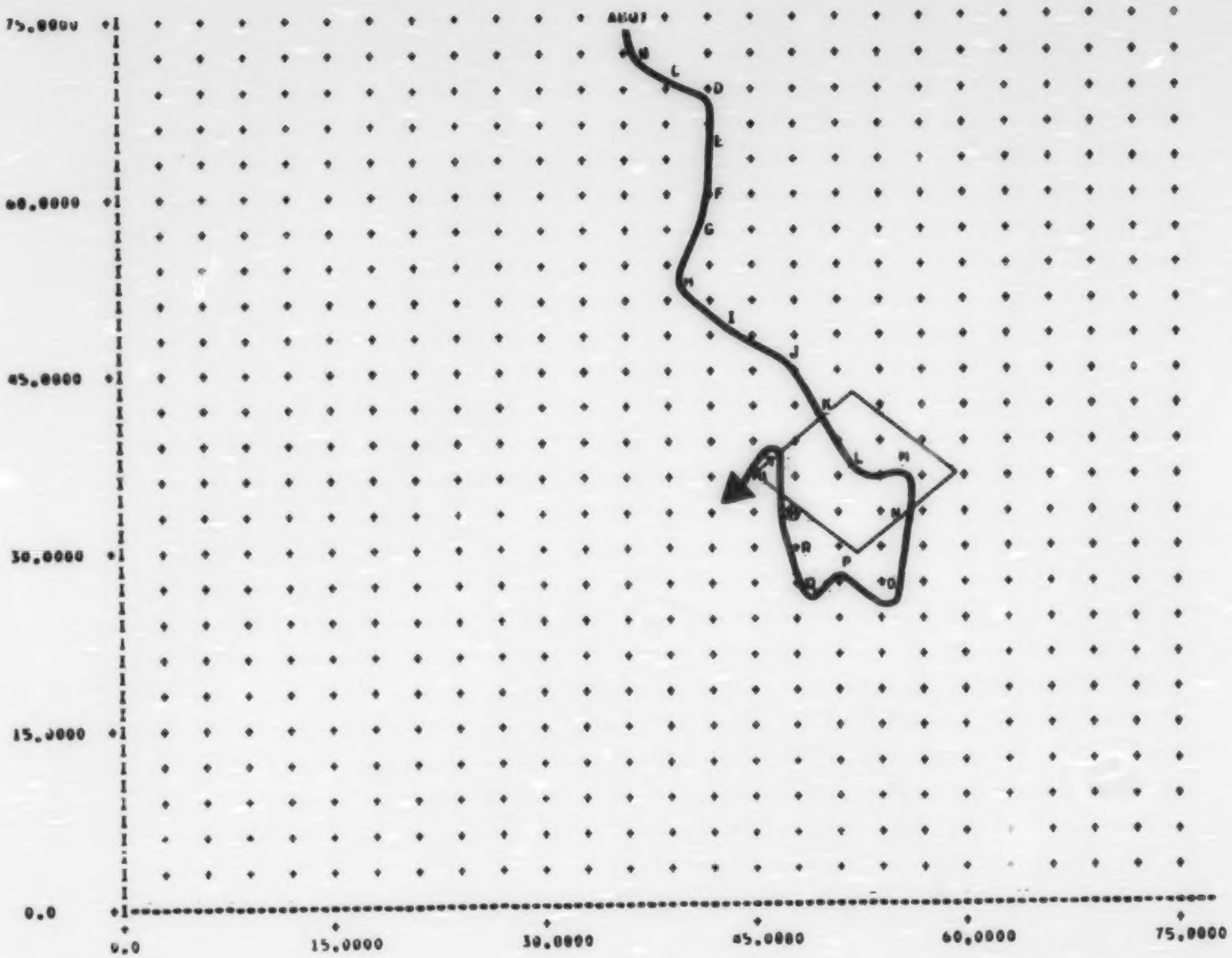
4 July 1976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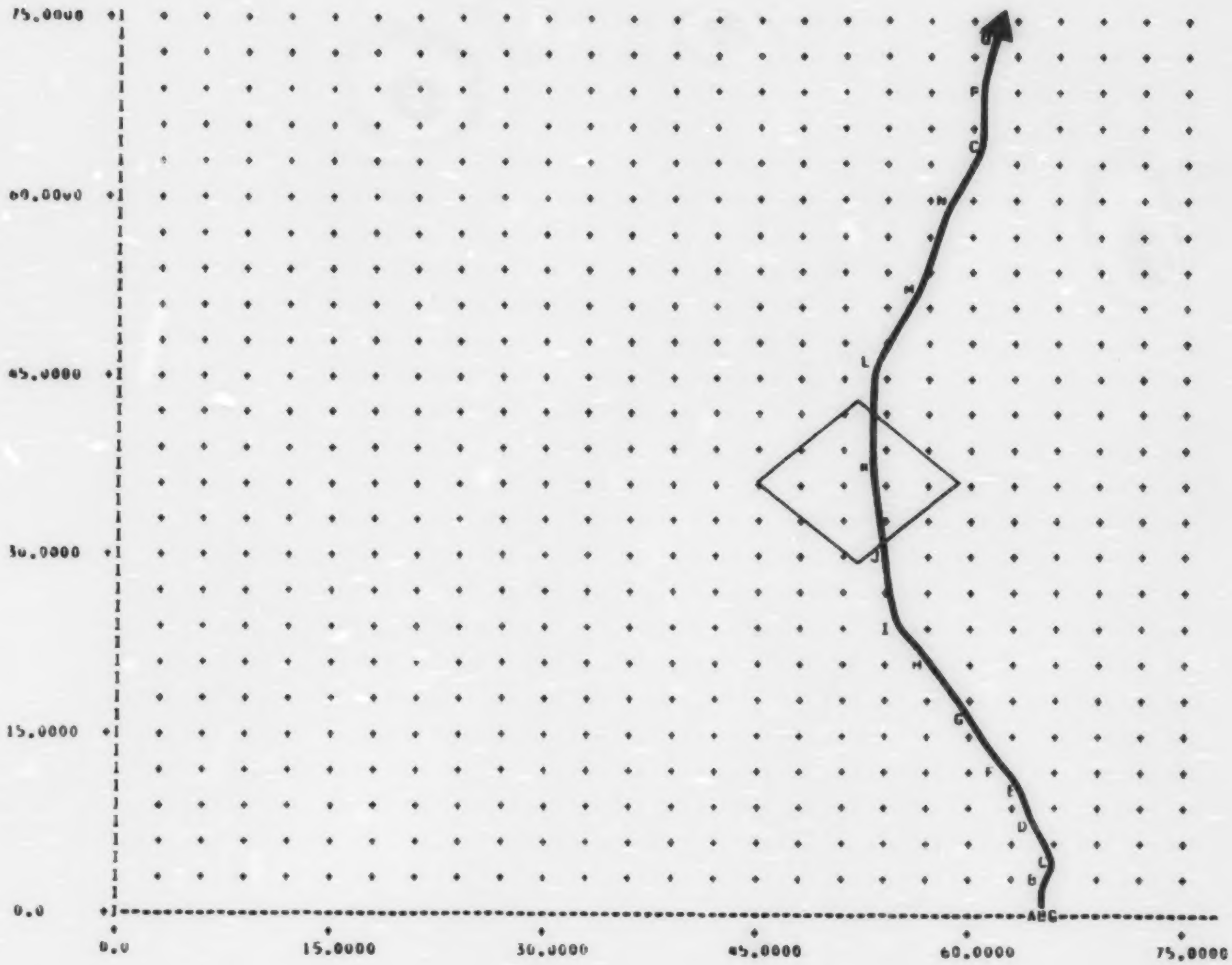
5 July 1976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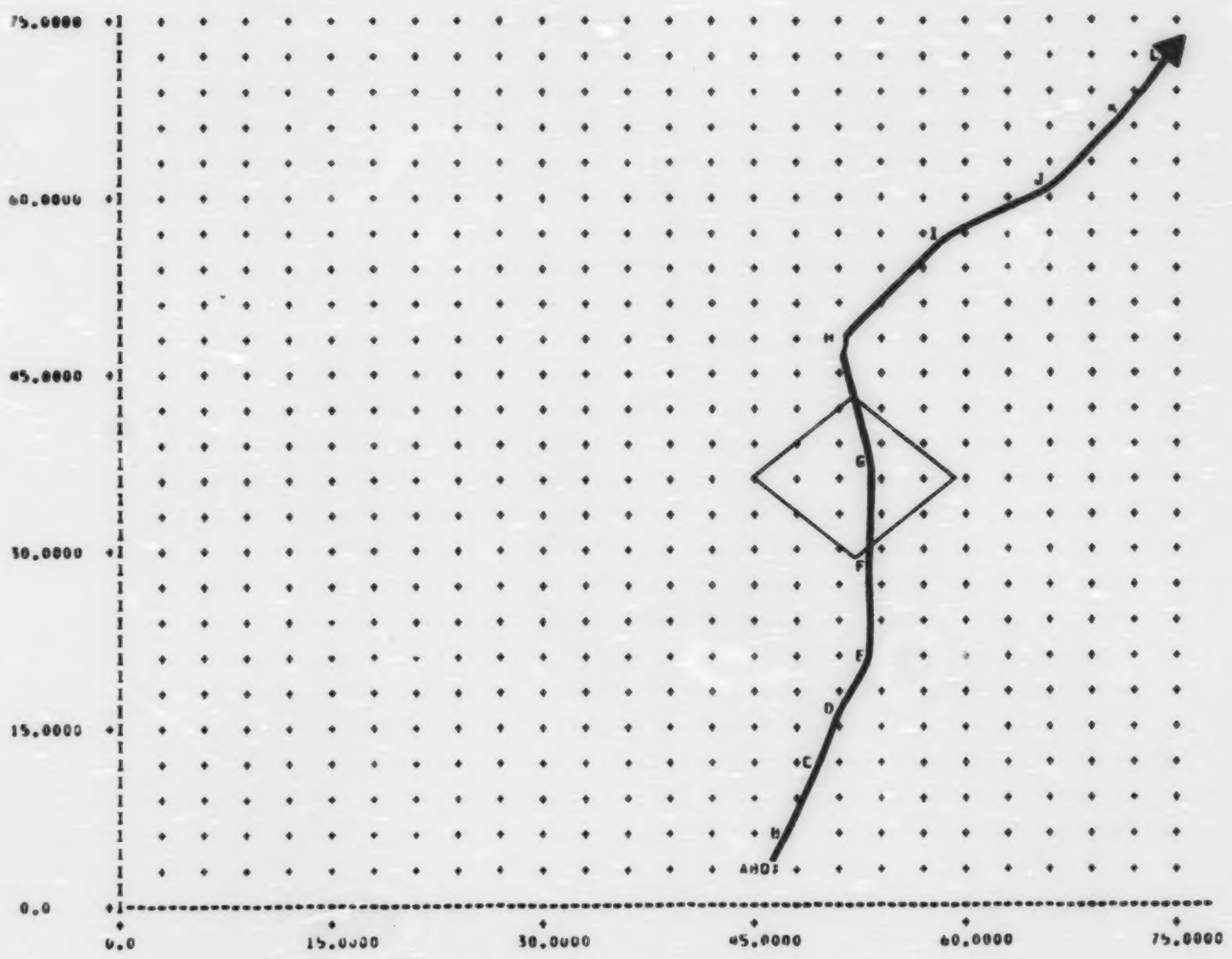
6 July 1976



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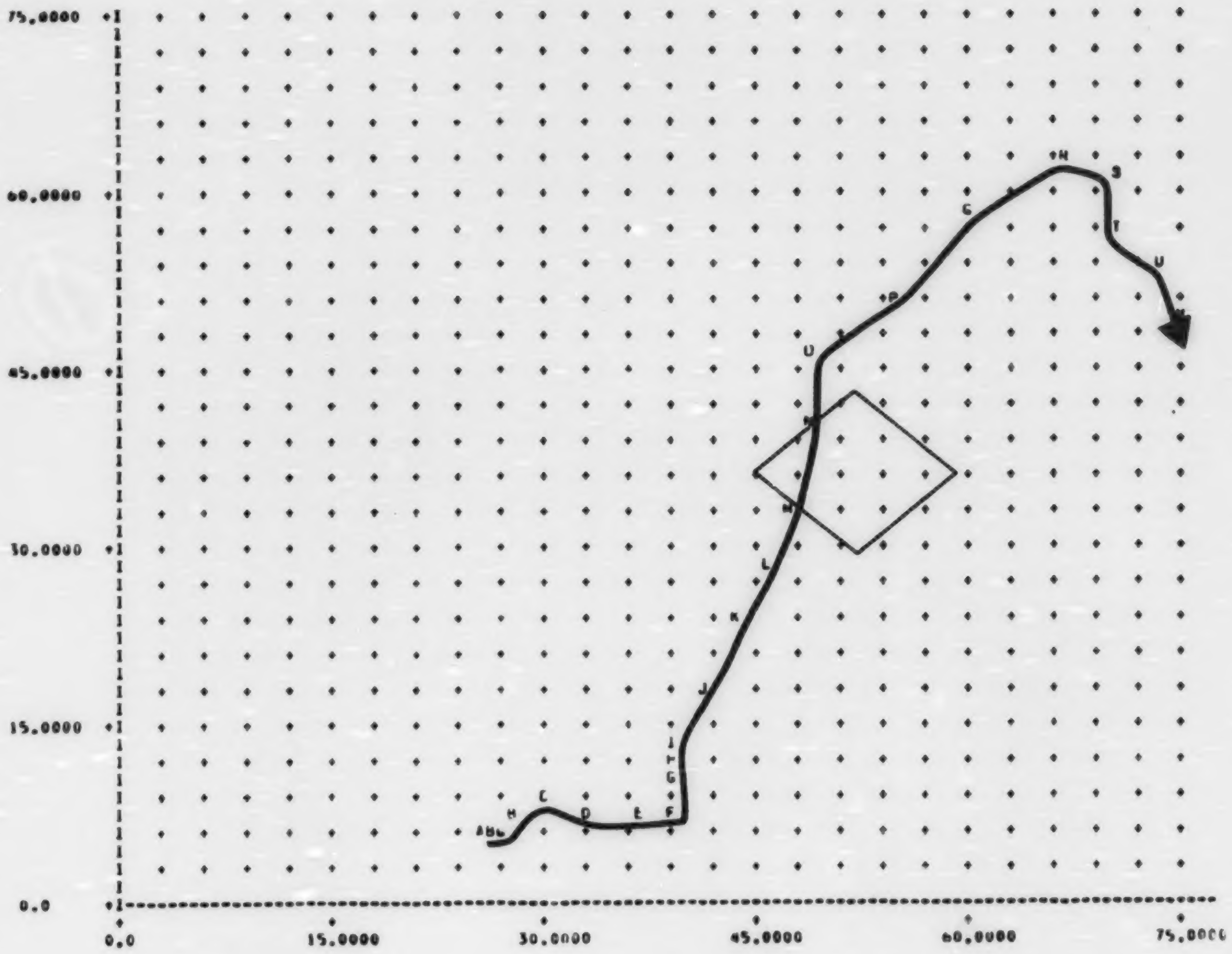
7 July 1976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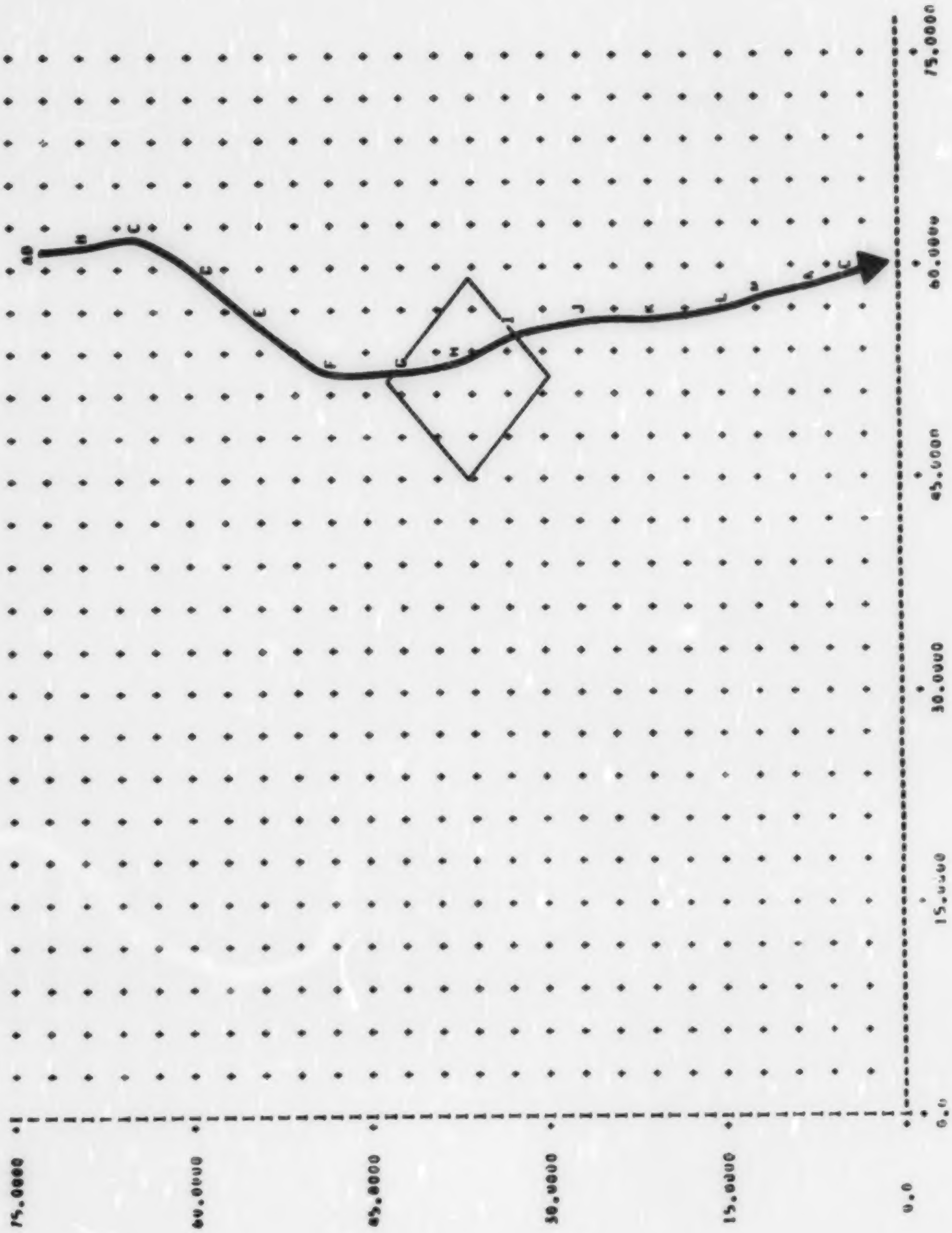
8 July 1976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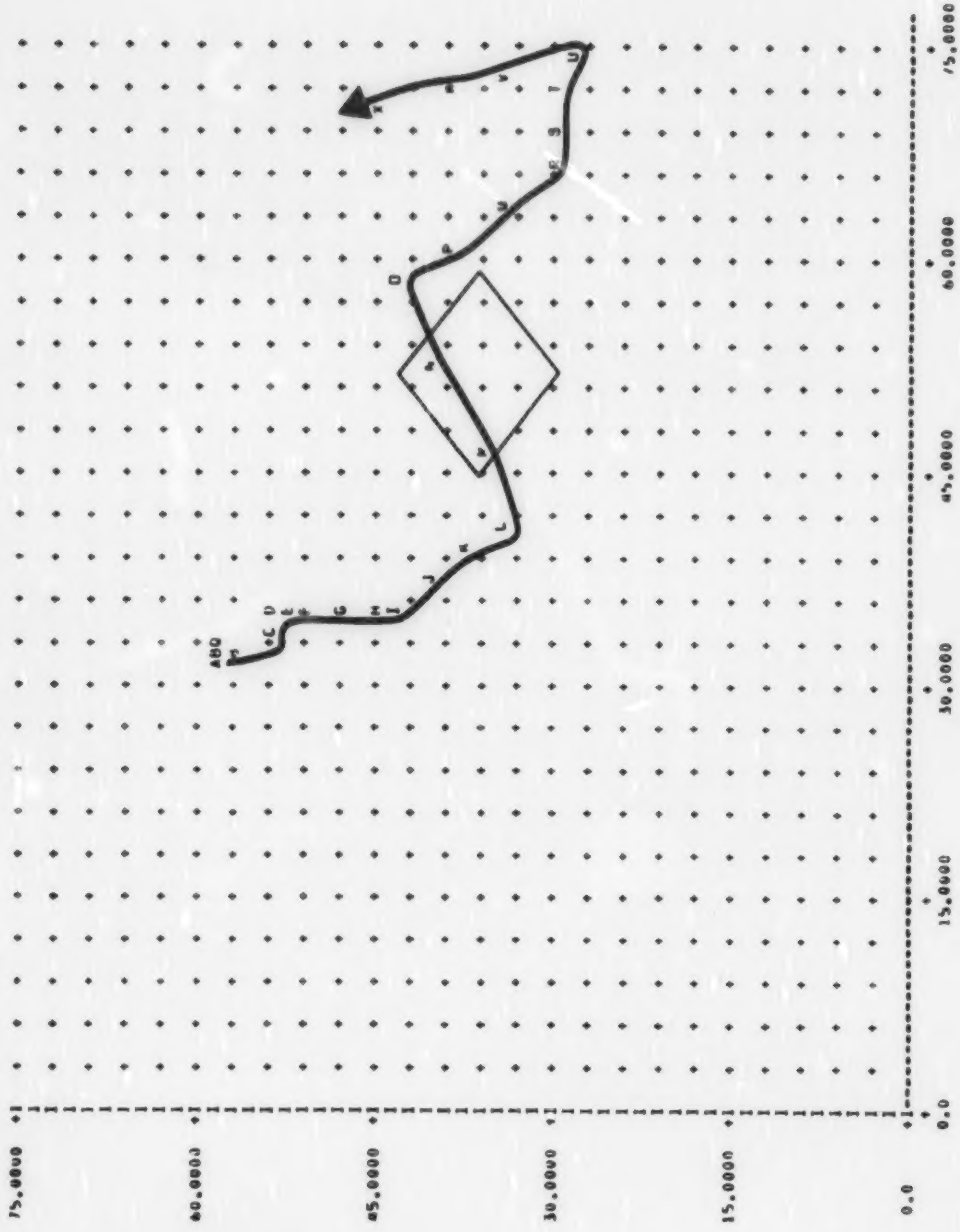
9 July 1976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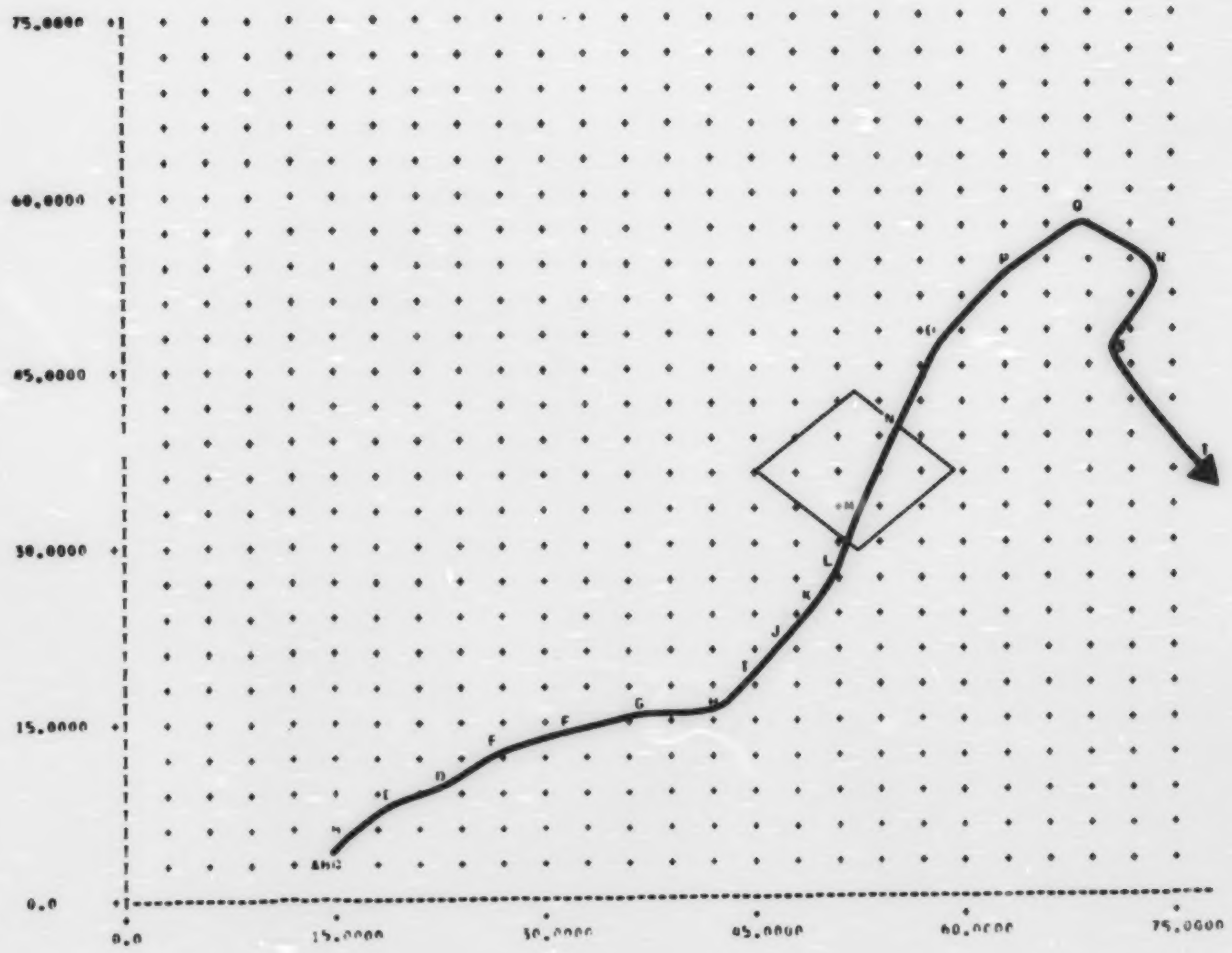
10 July 1976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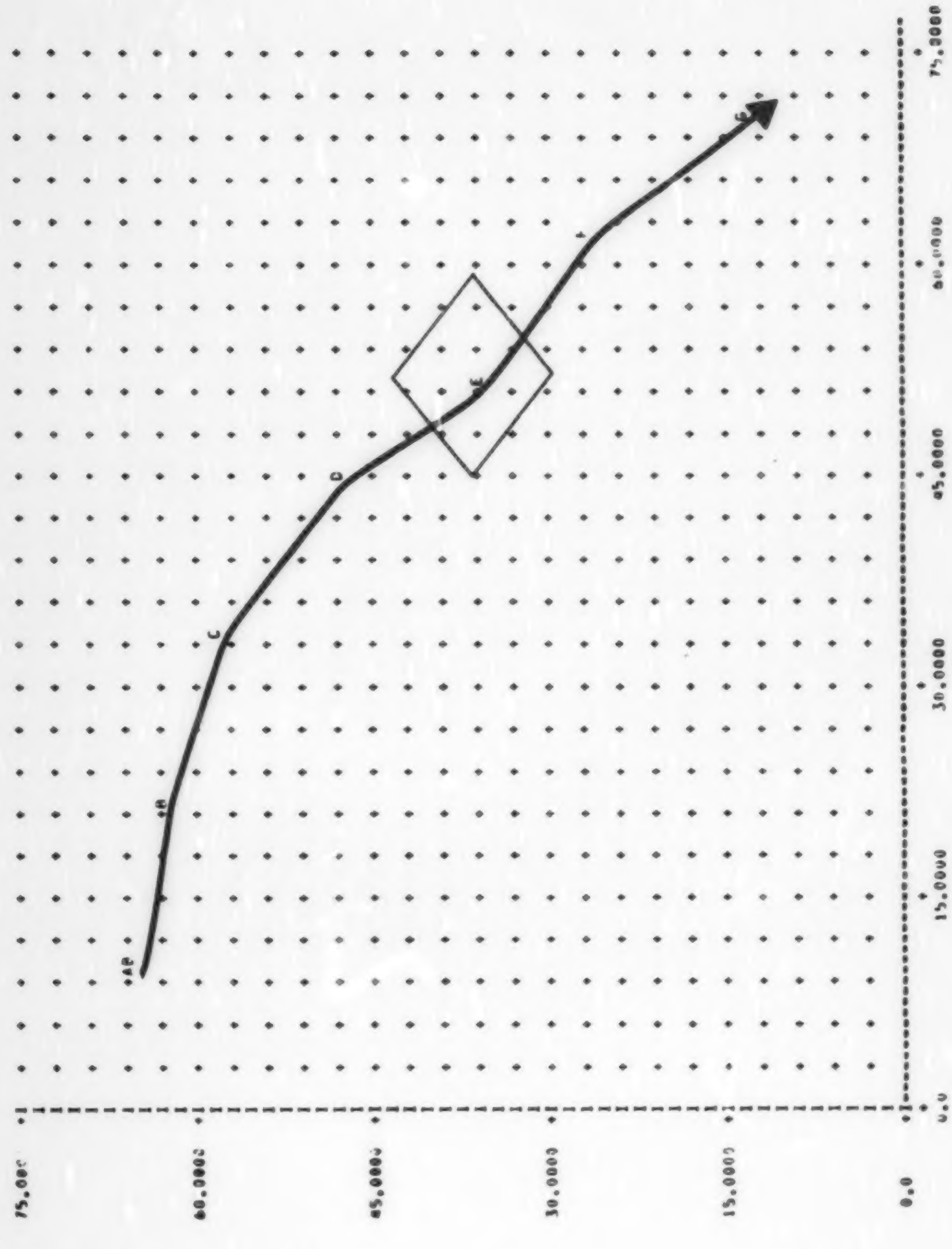
11 July 1976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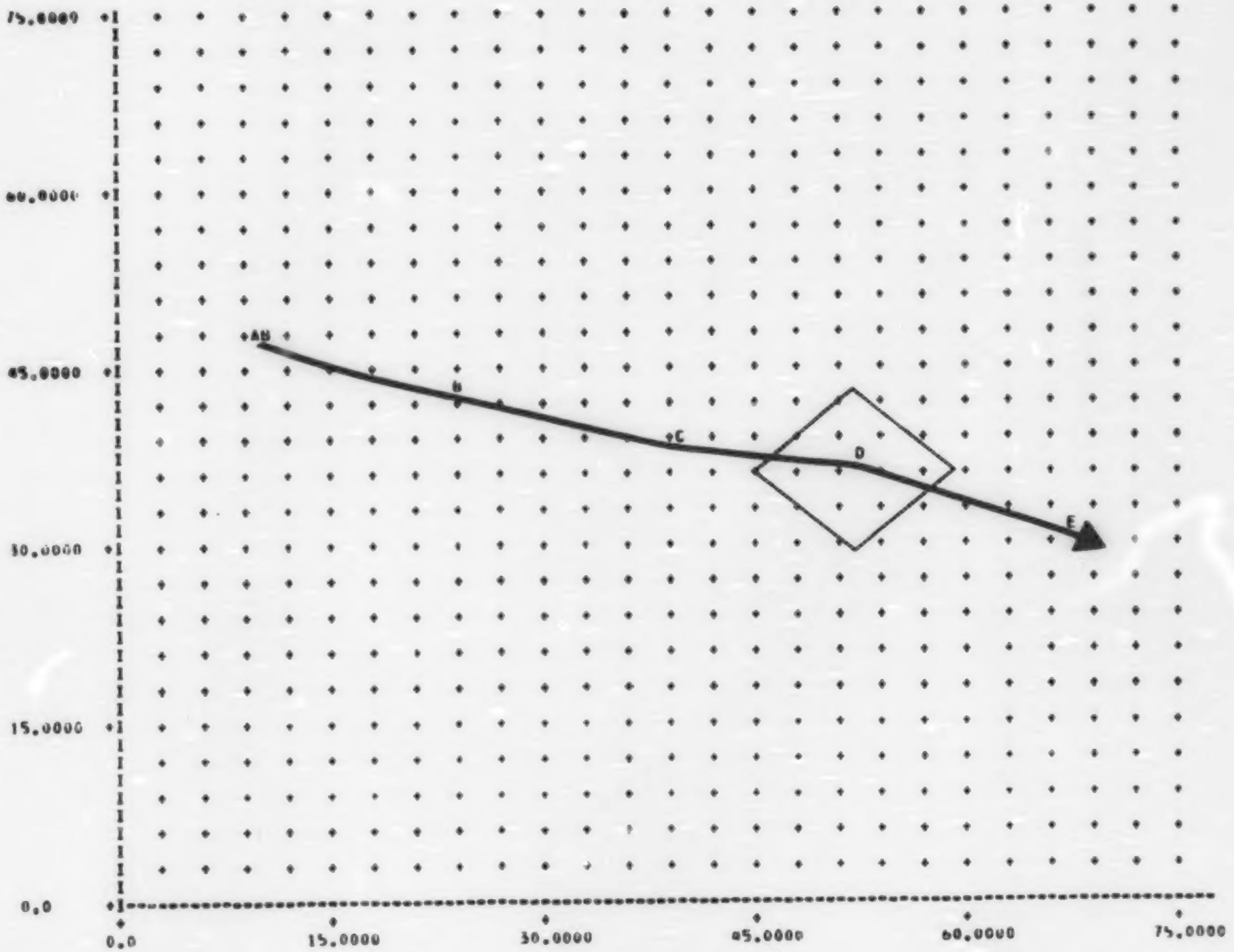
12 July 1976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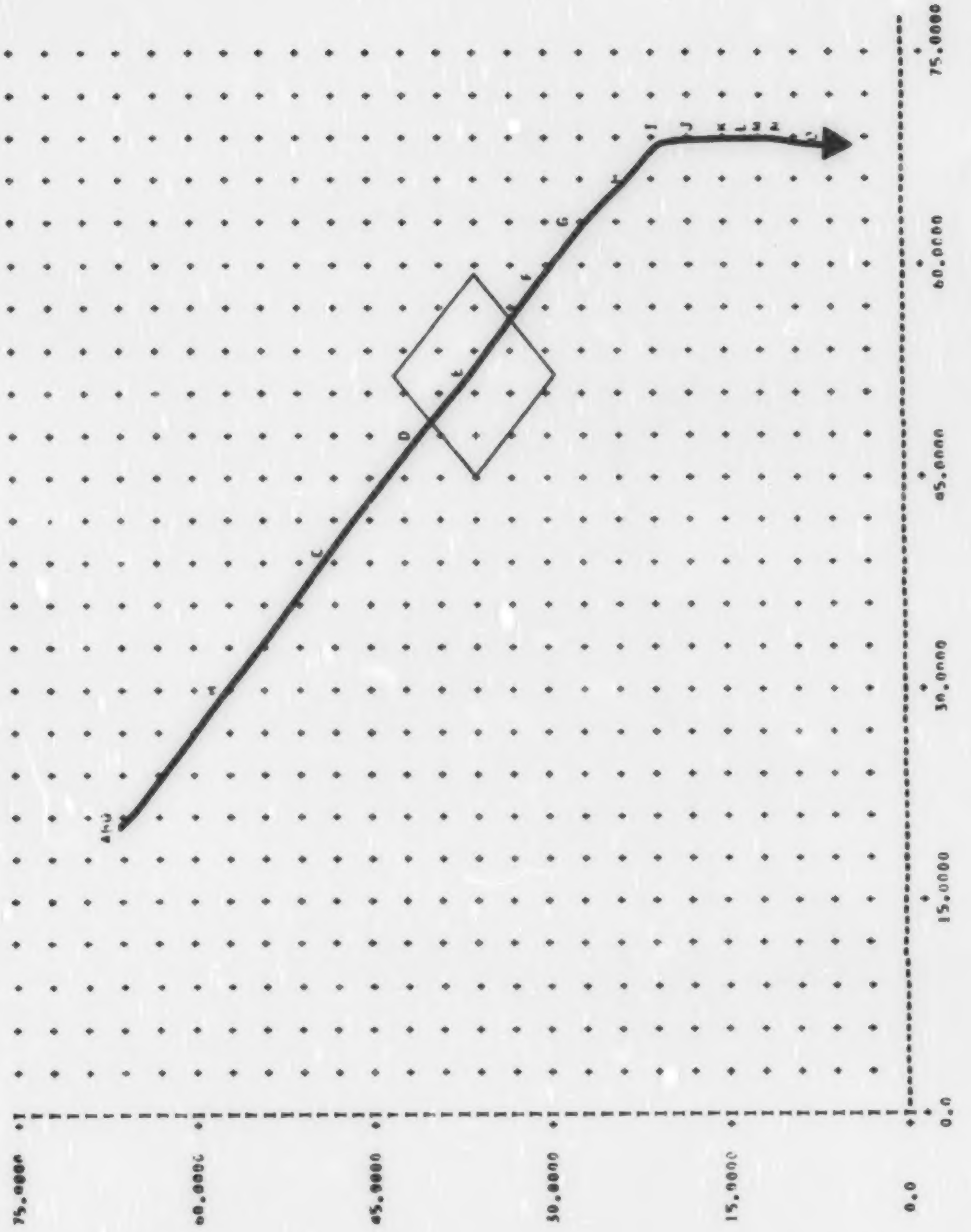
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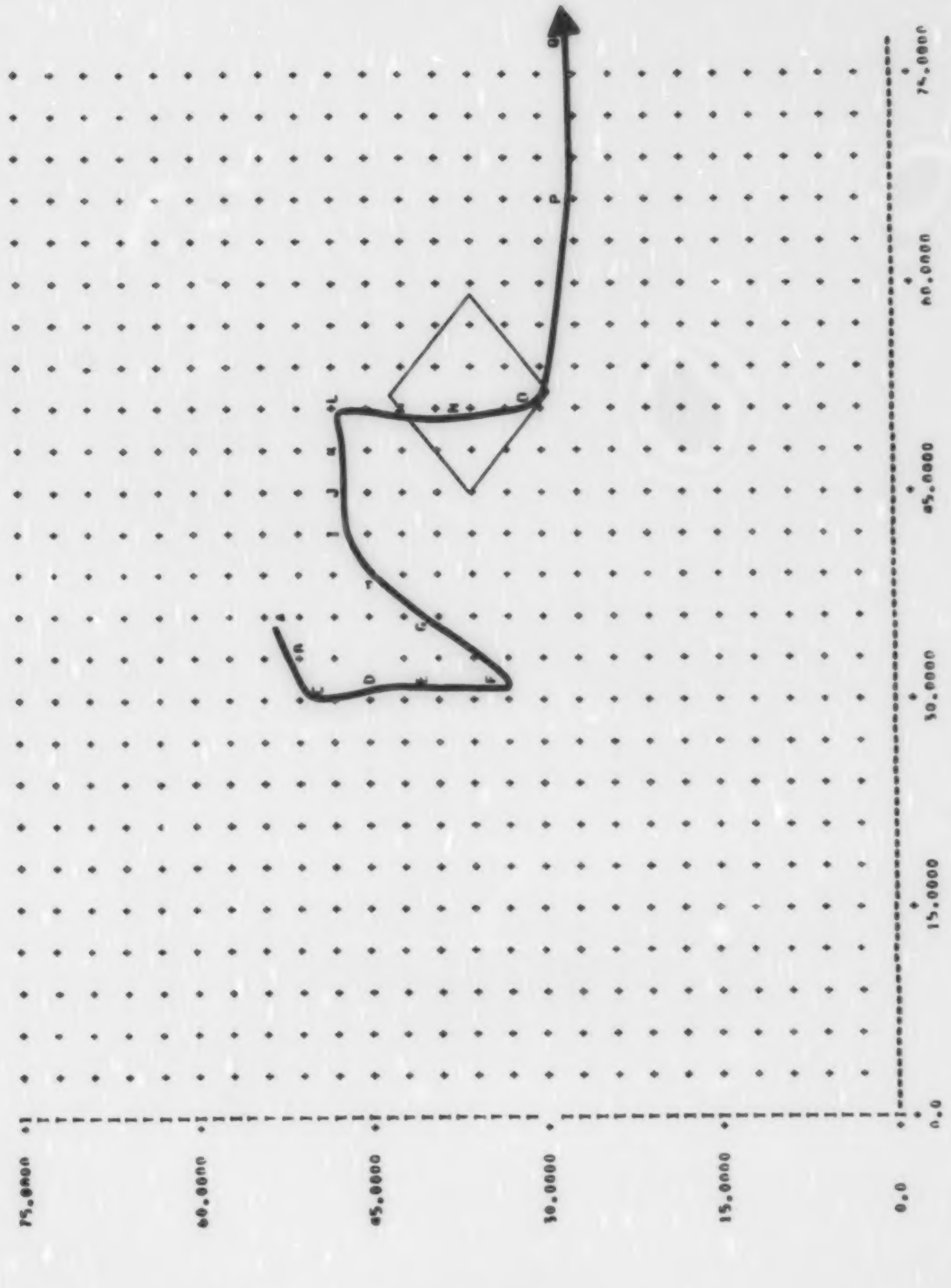
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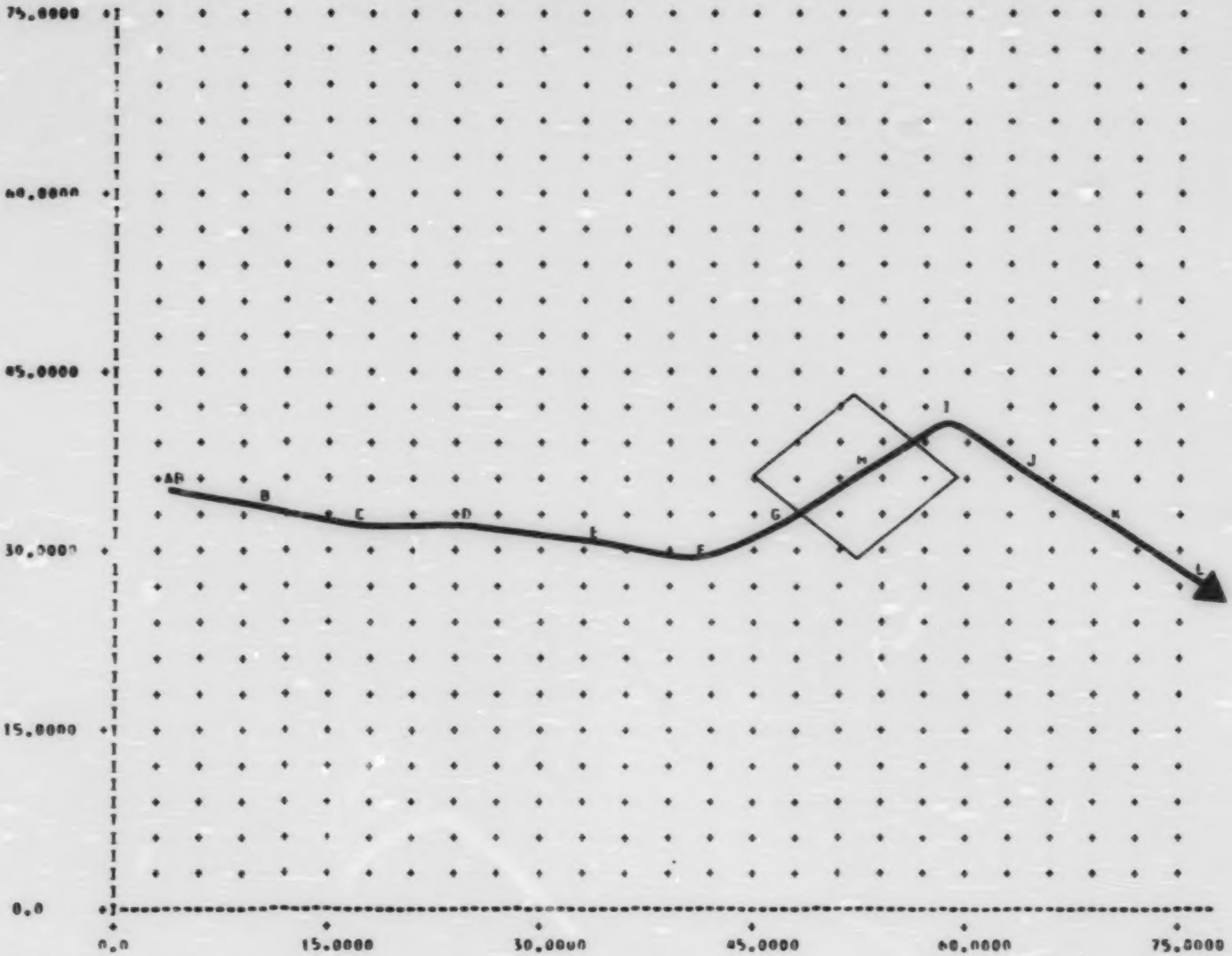
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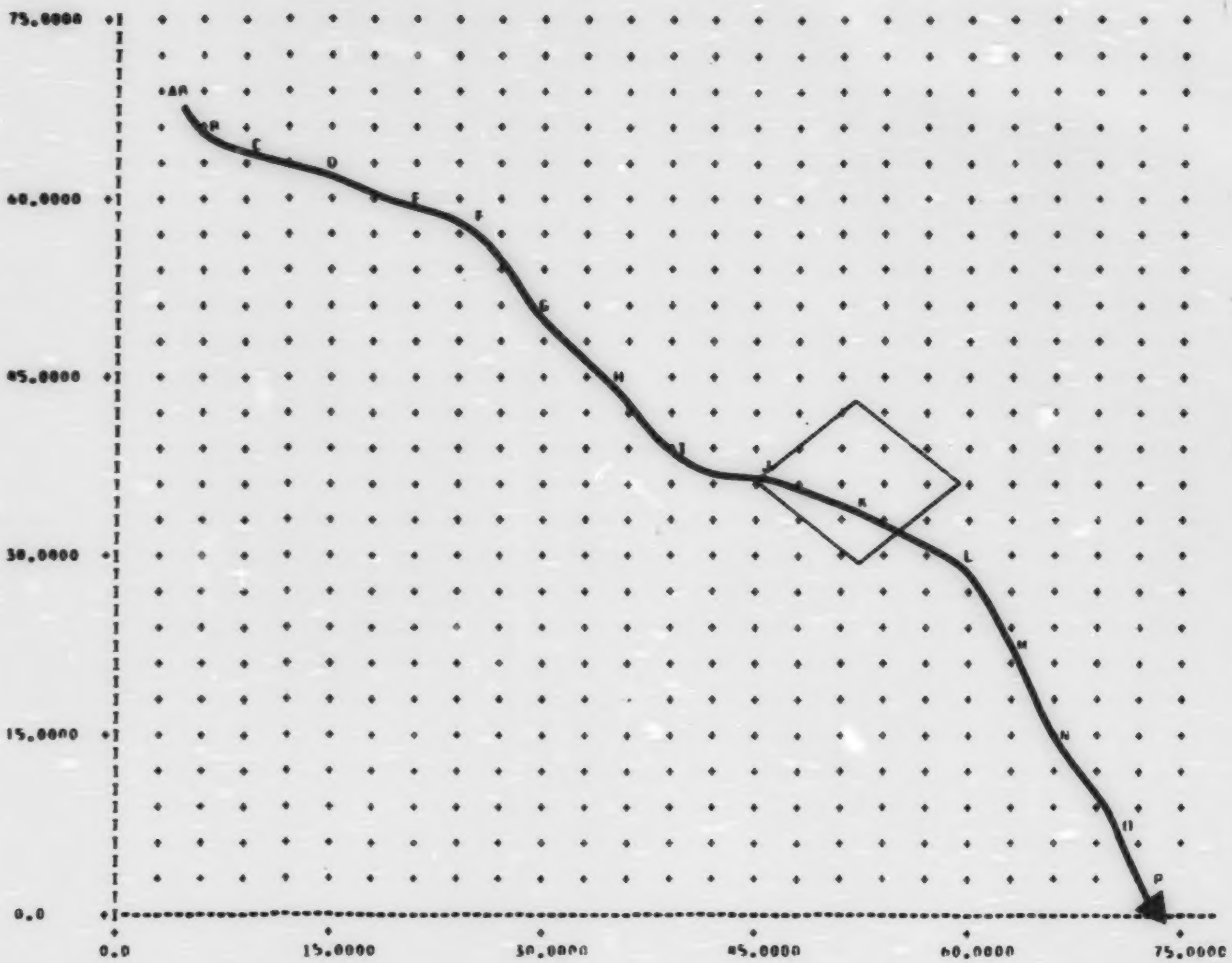
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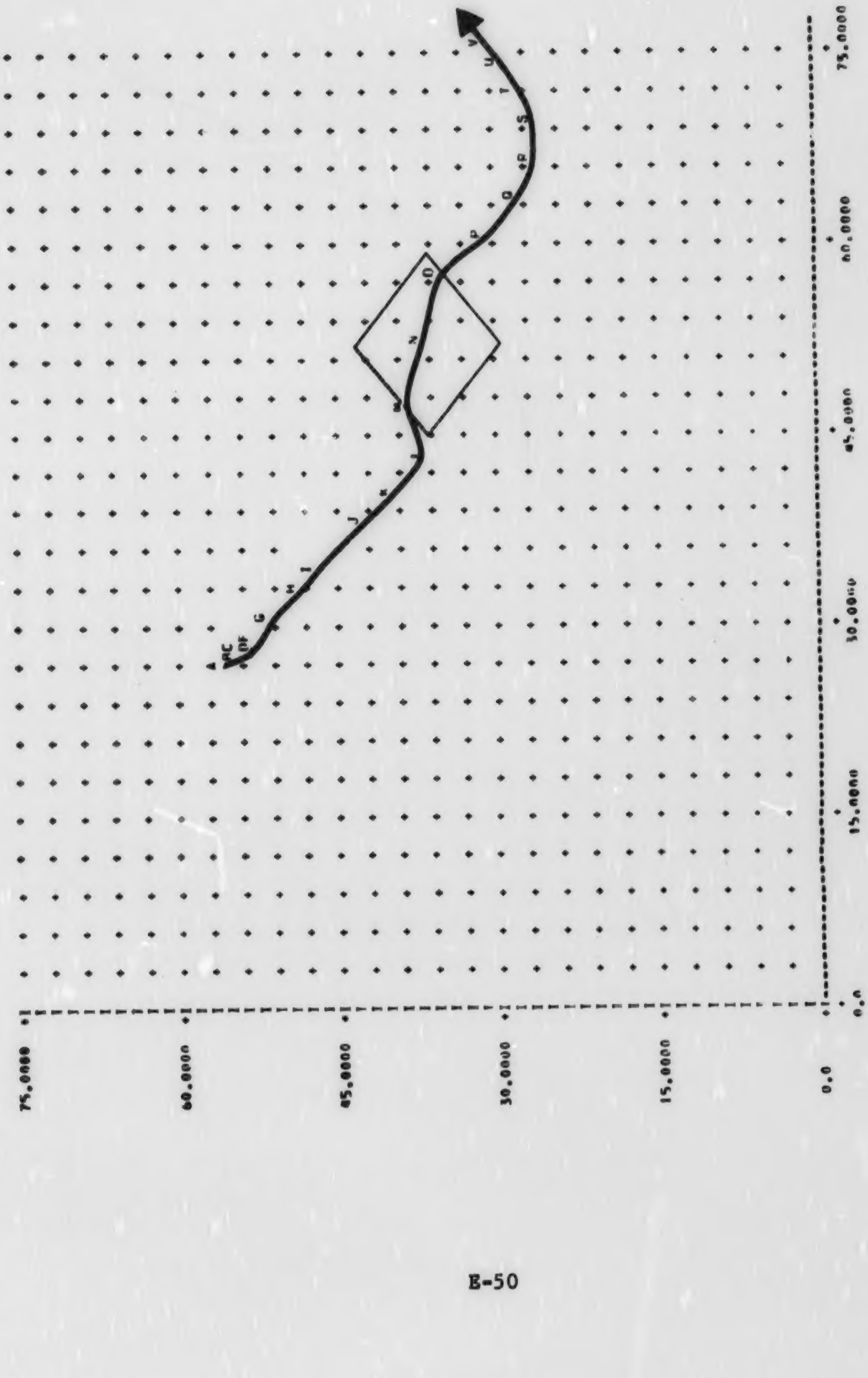
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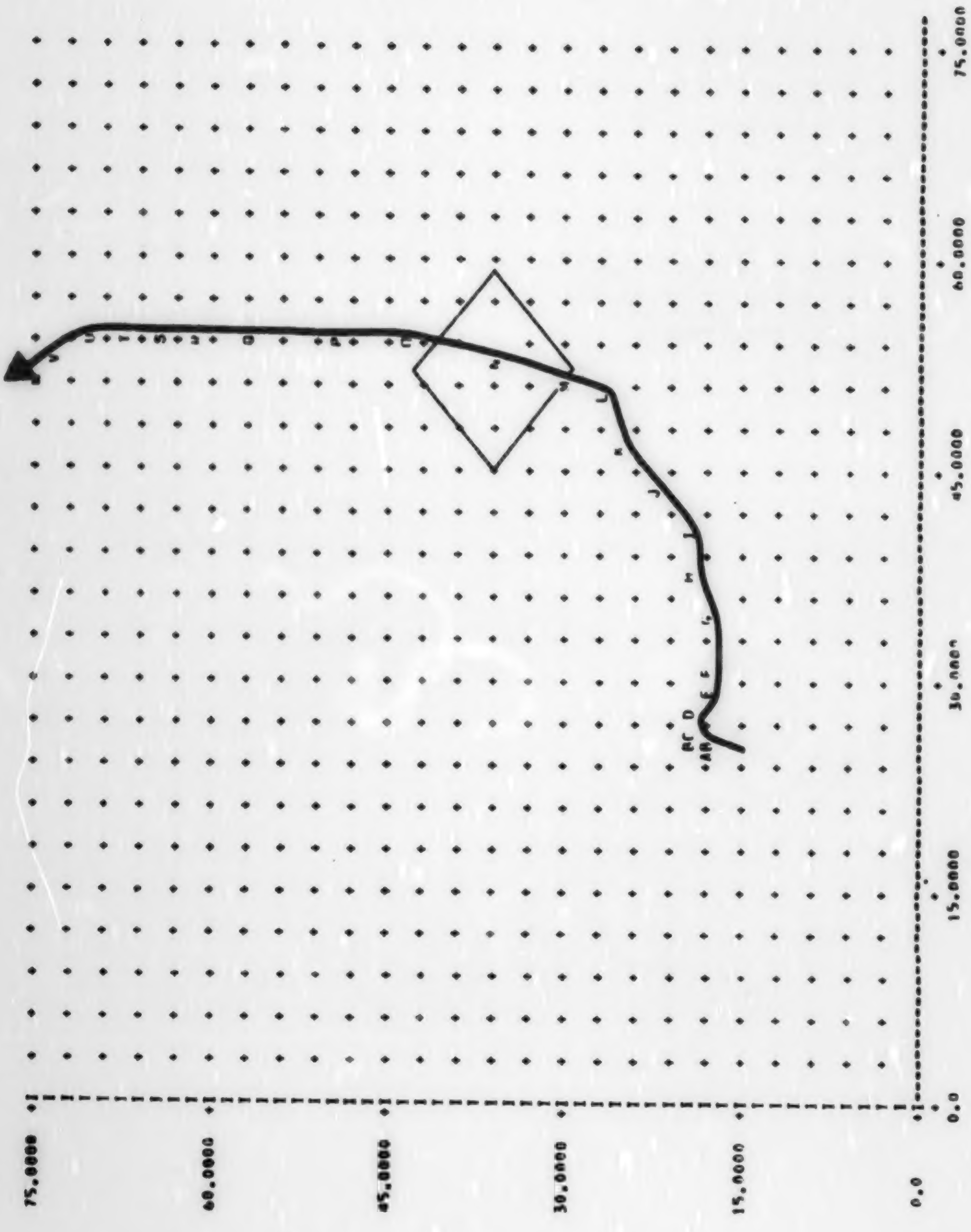

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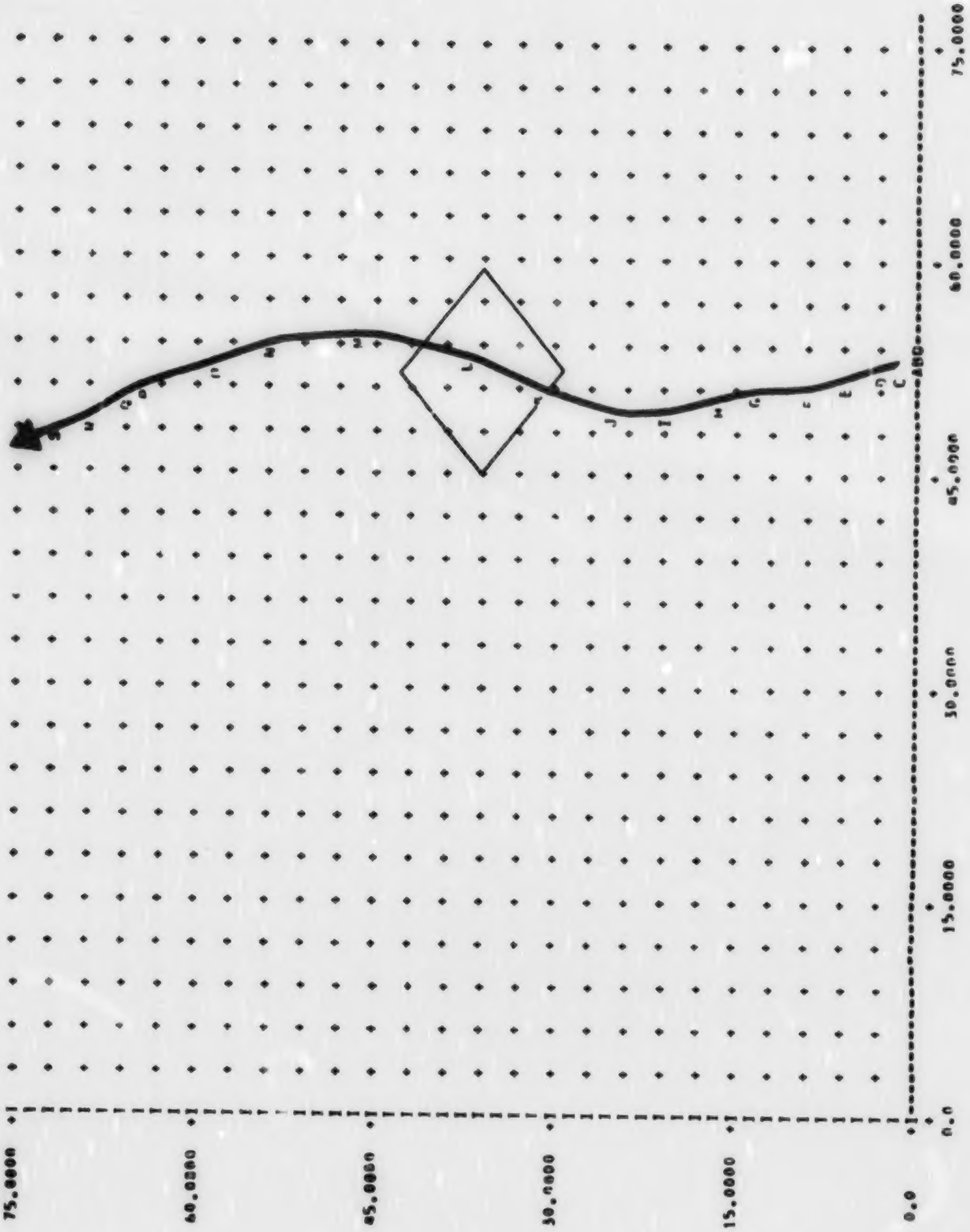
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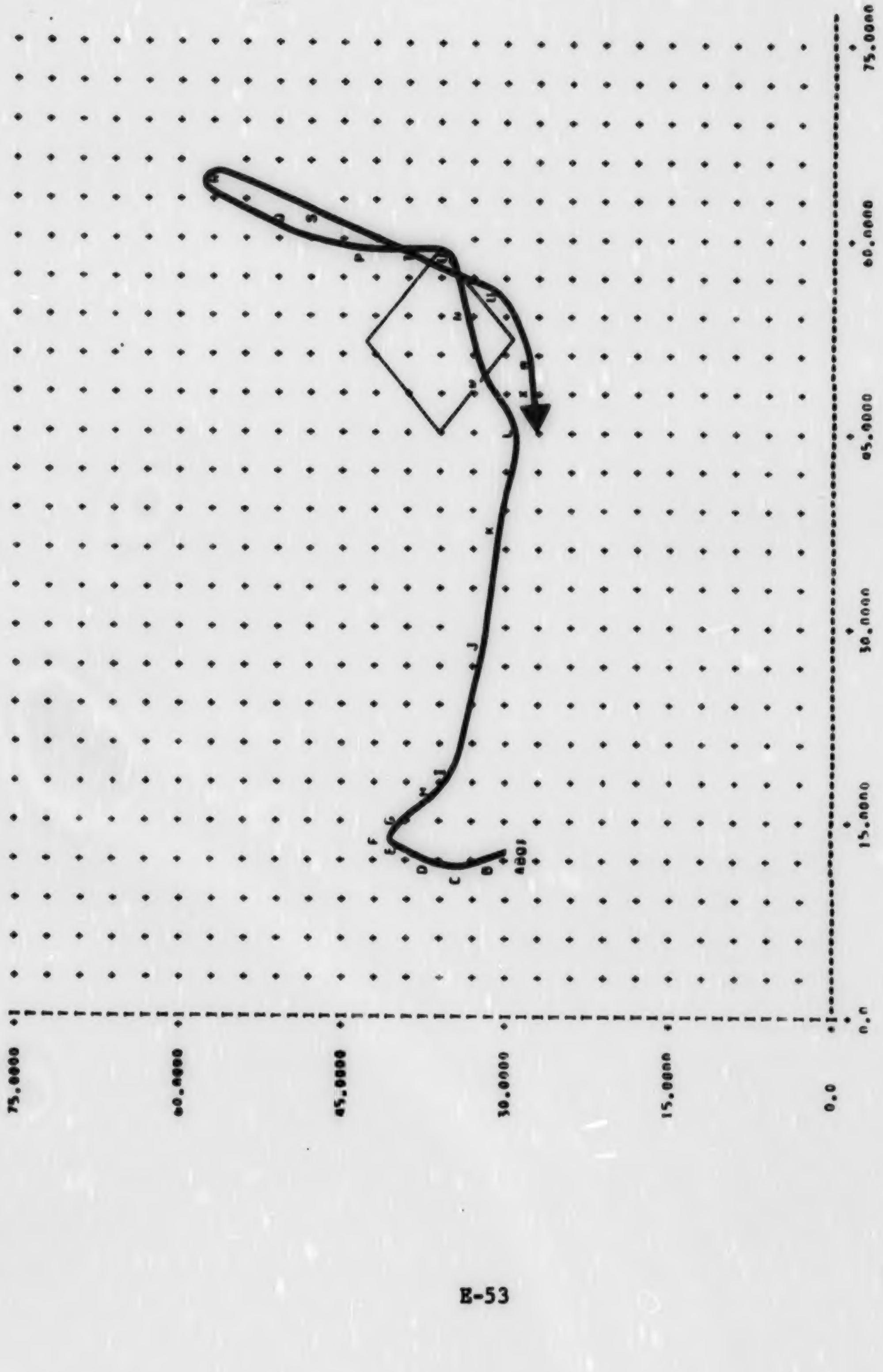
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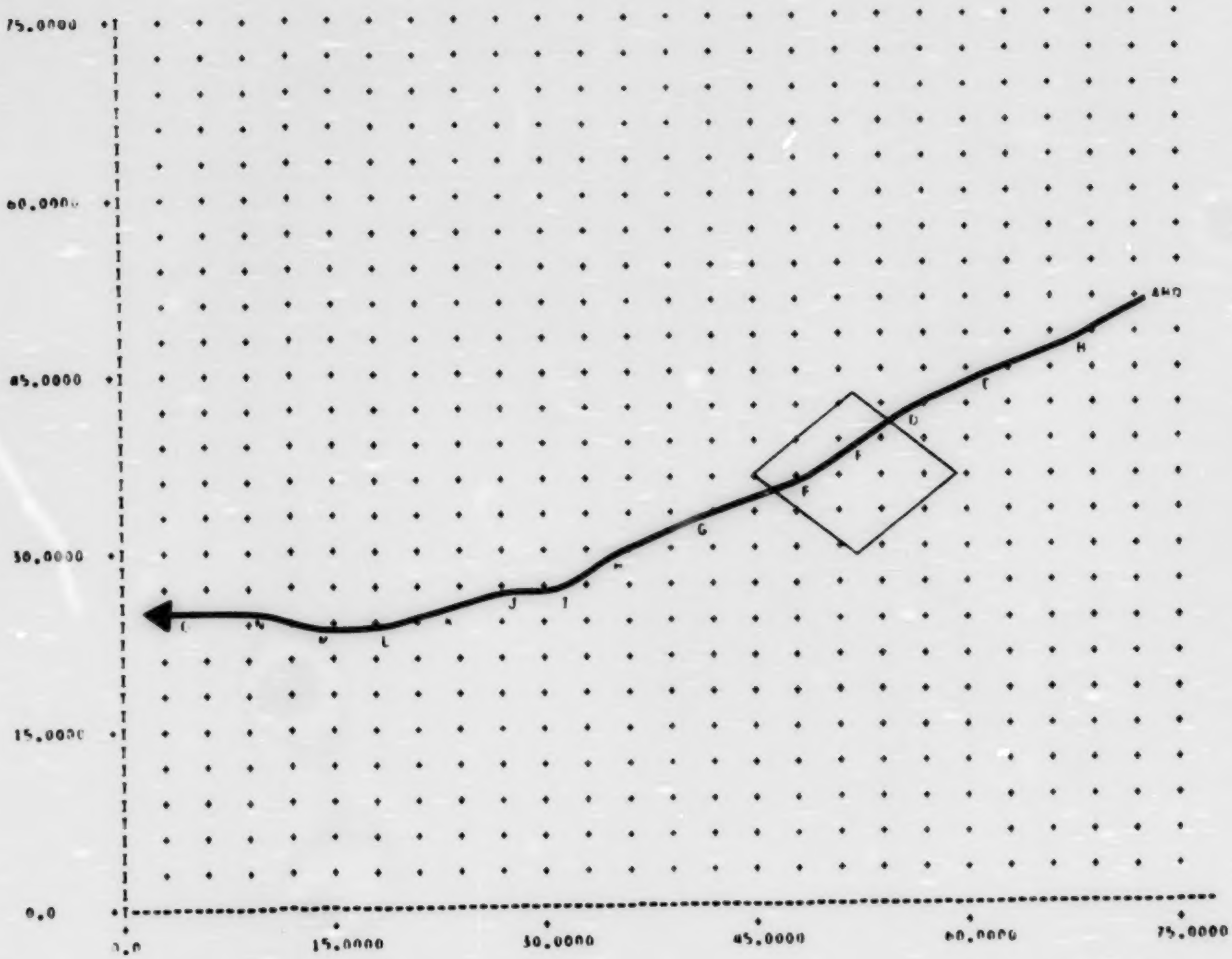
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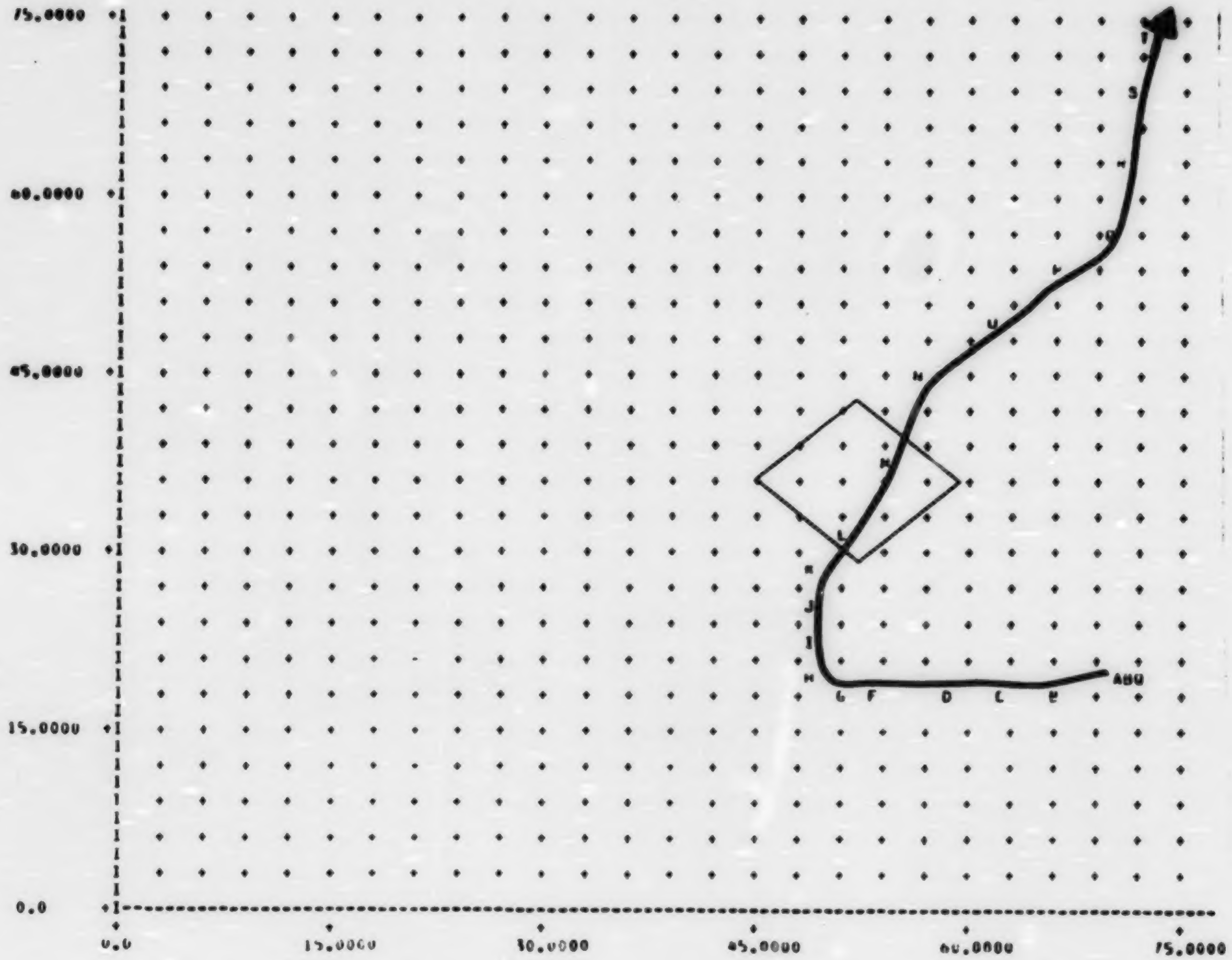
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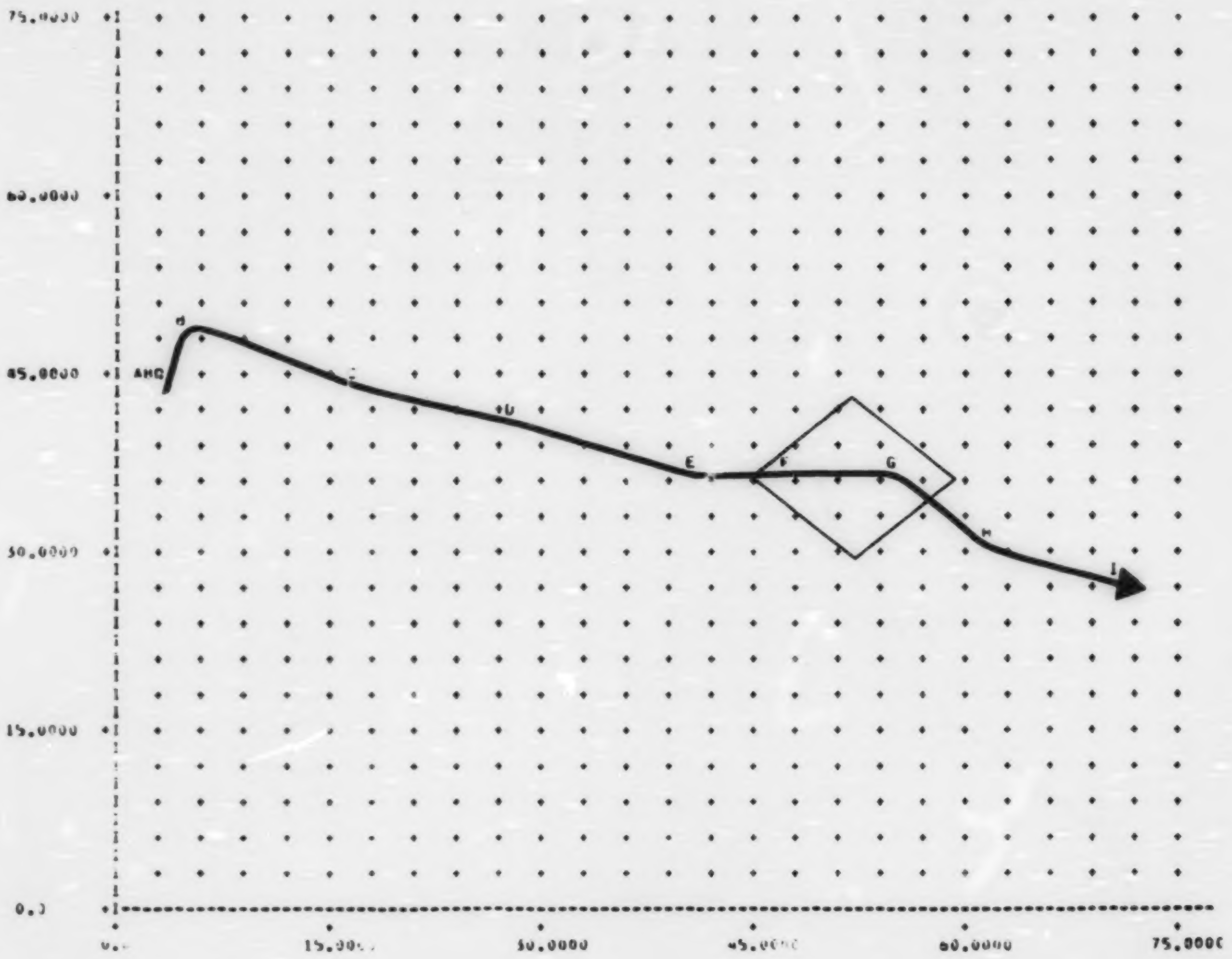
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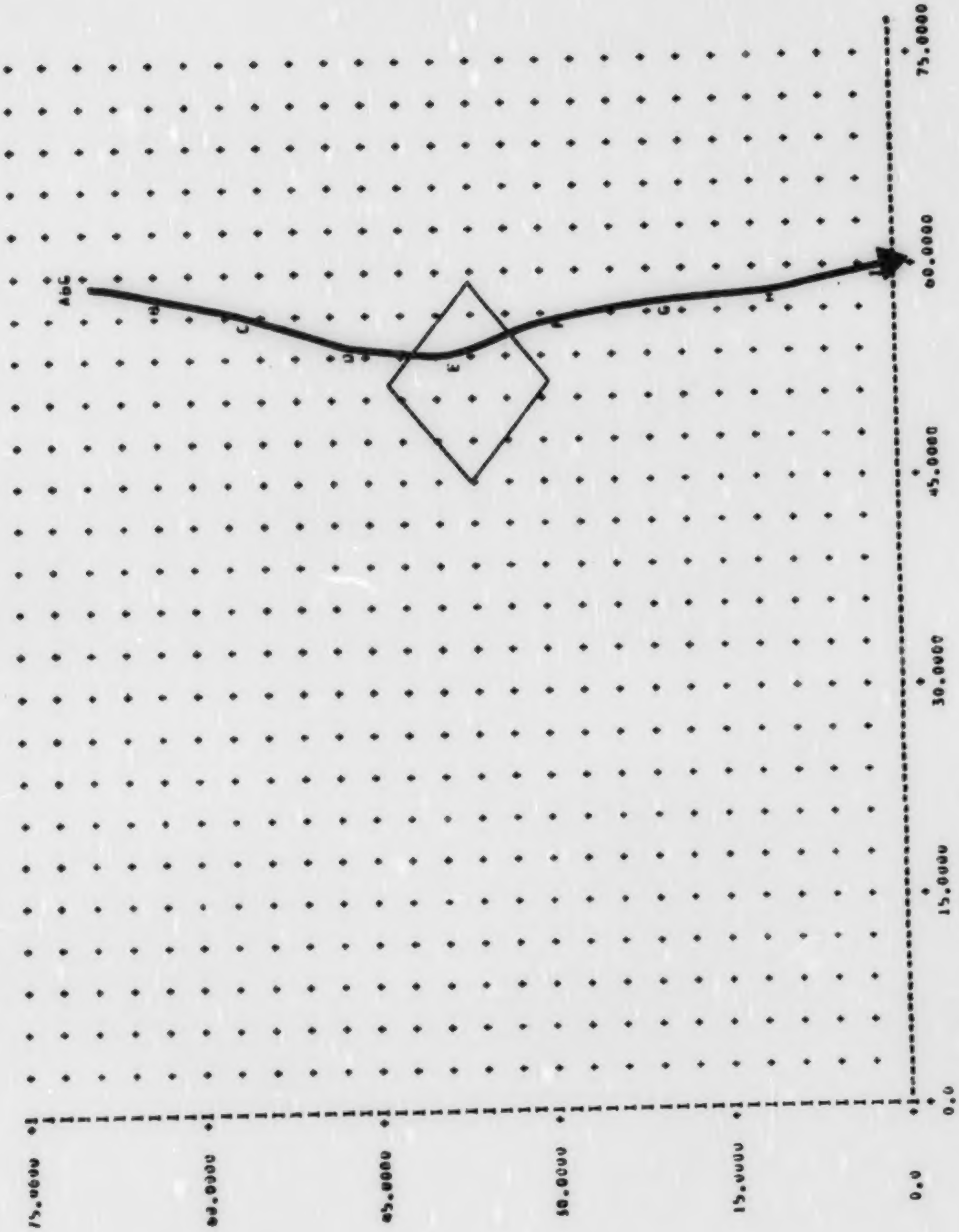

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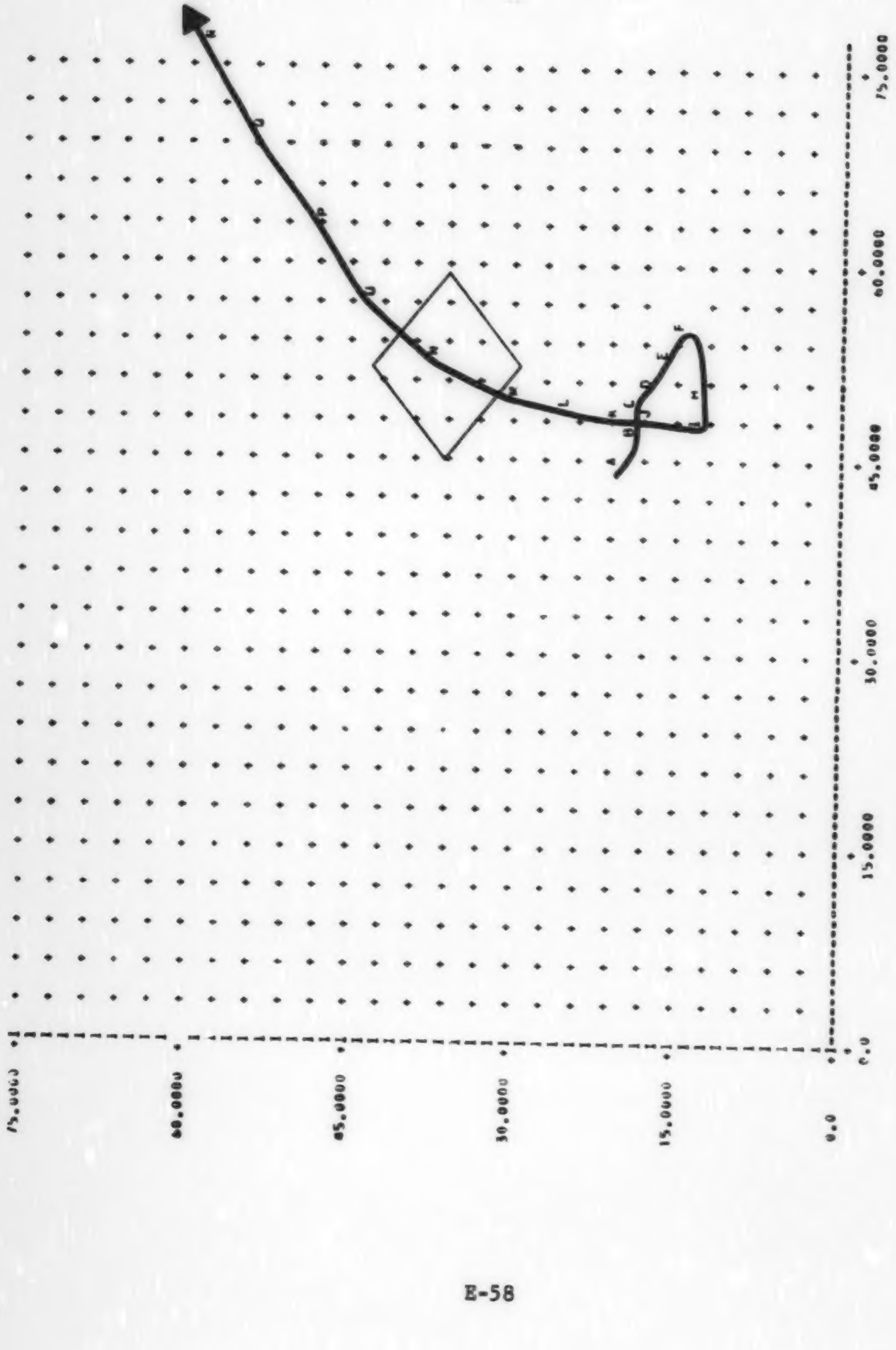
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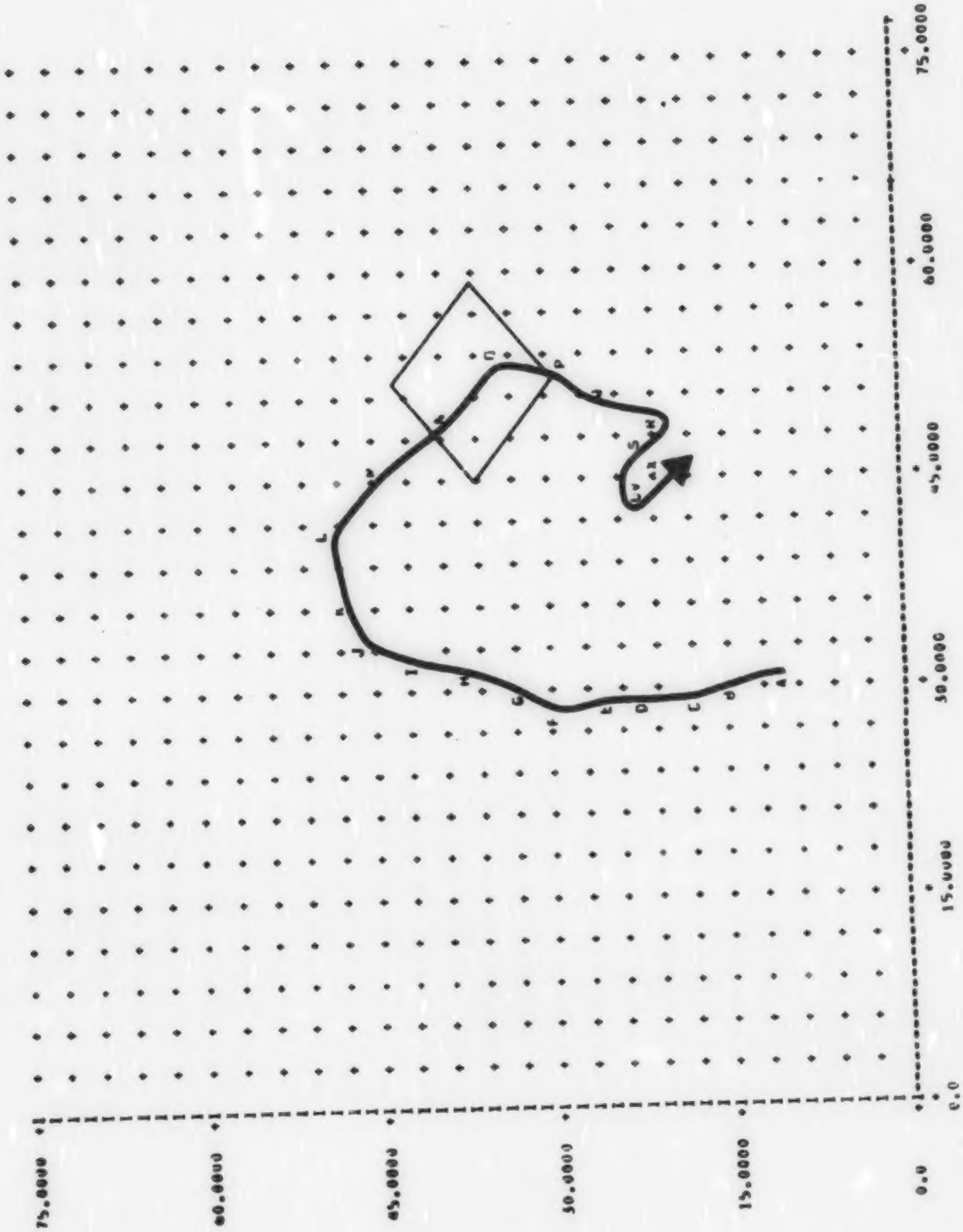
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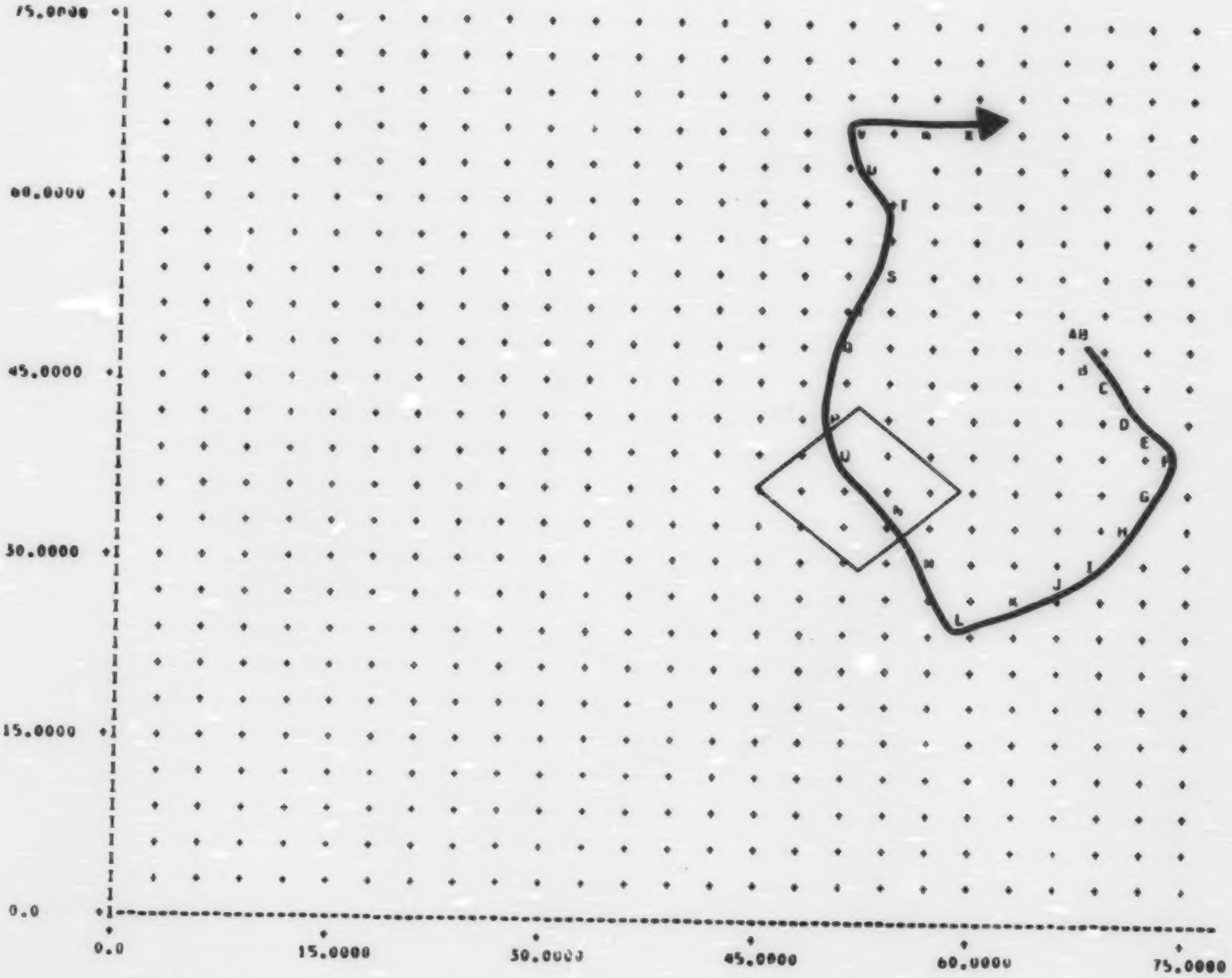
27 July 1976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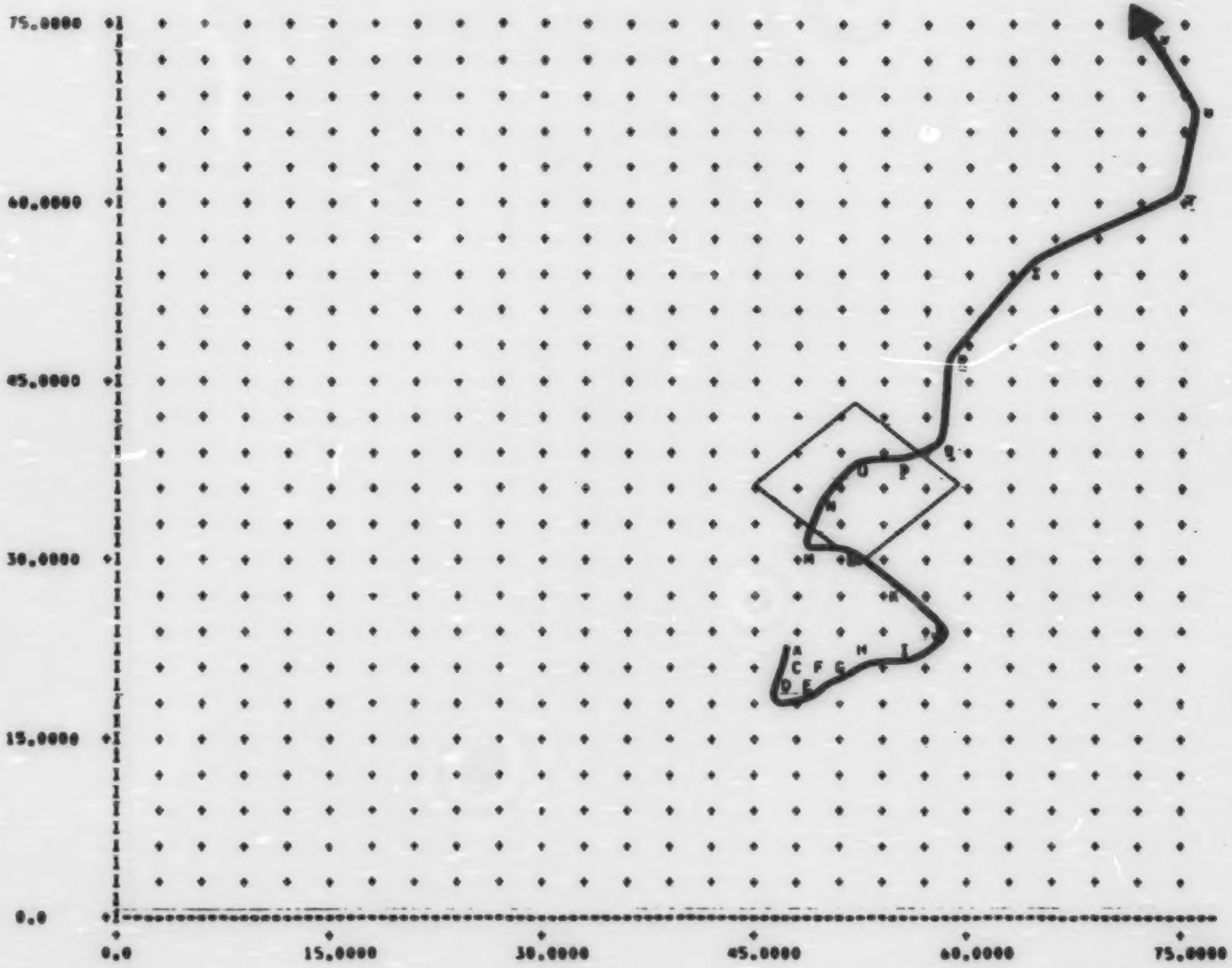
28 July 1976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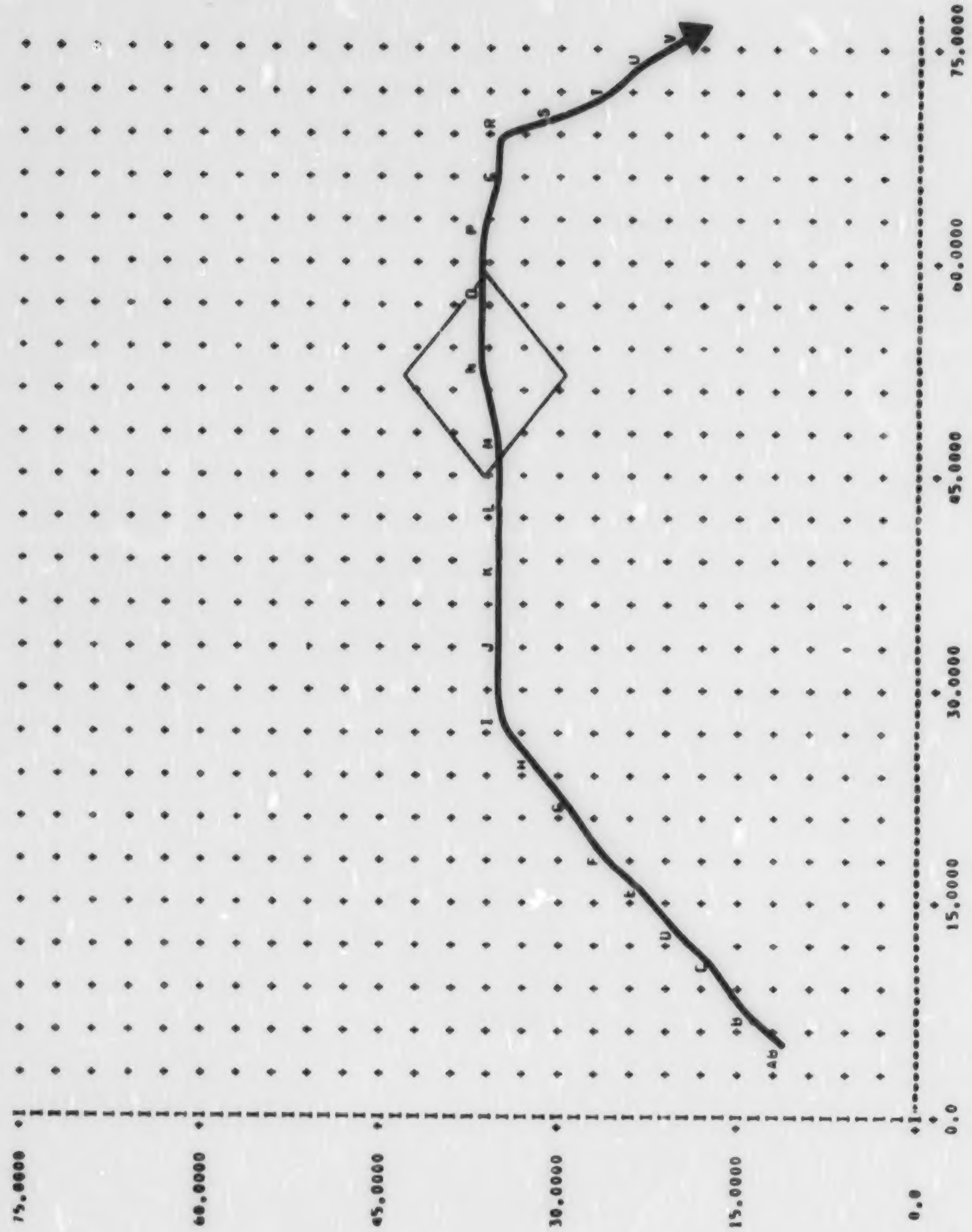0.0
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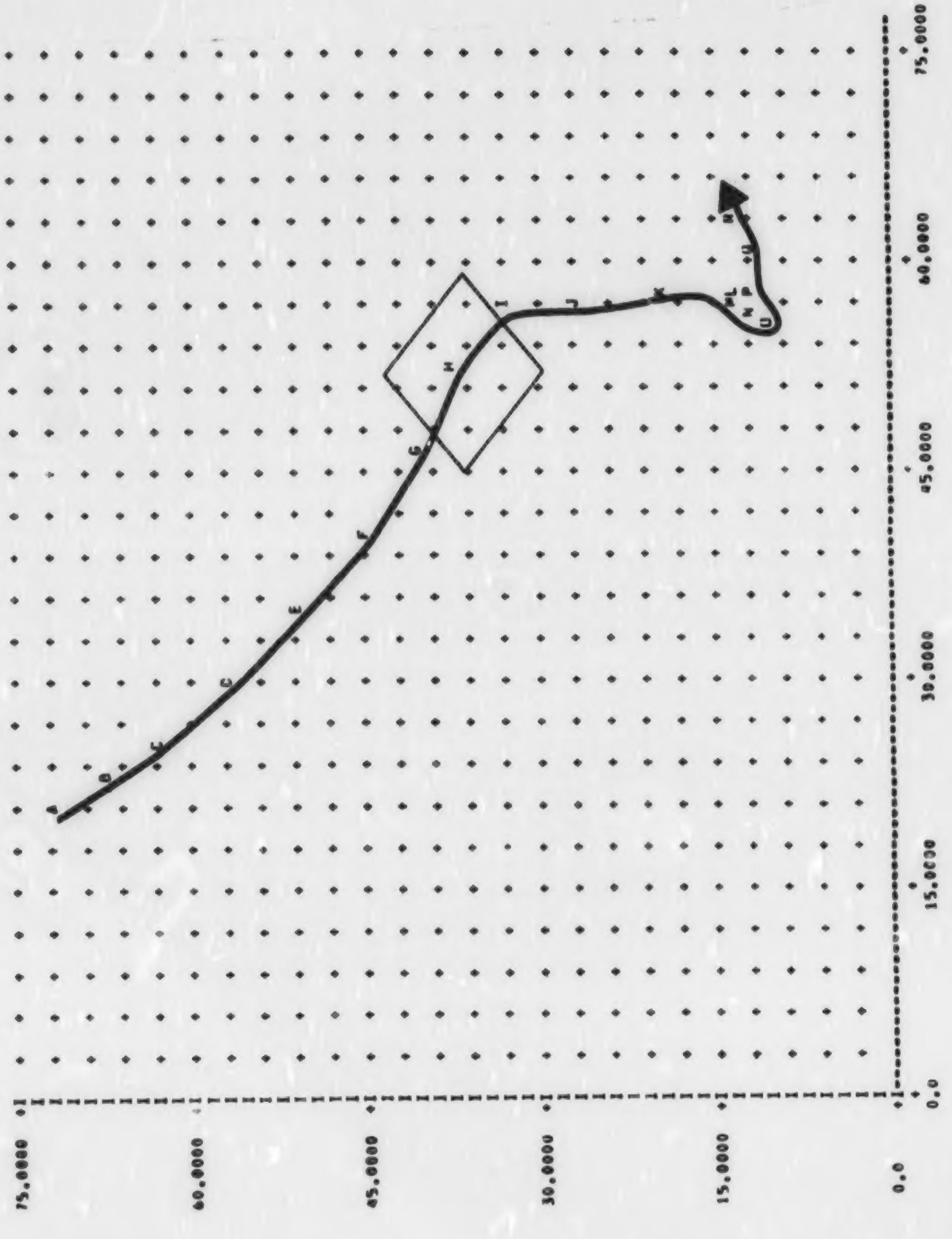
30 July 1976



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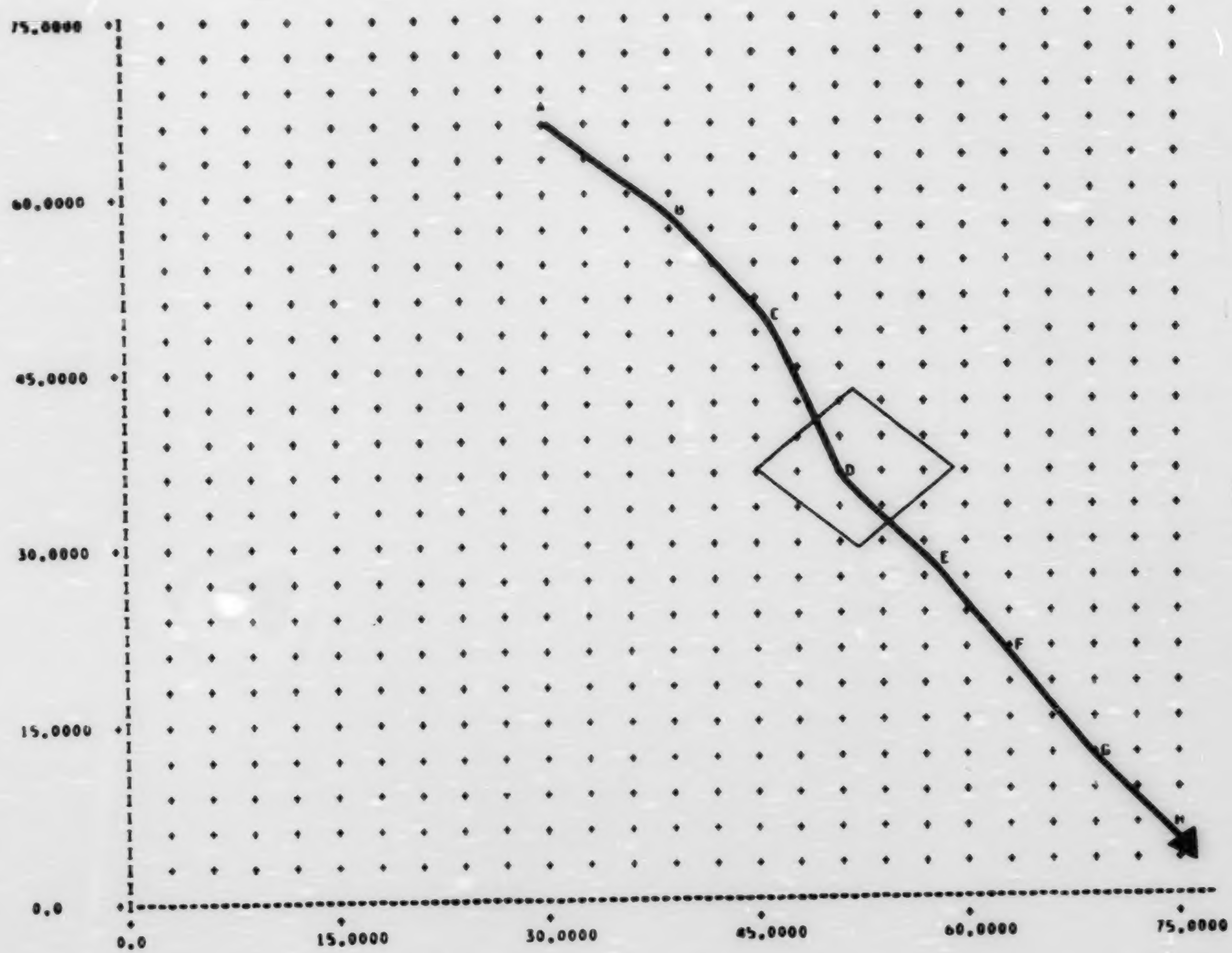
31 July 1976



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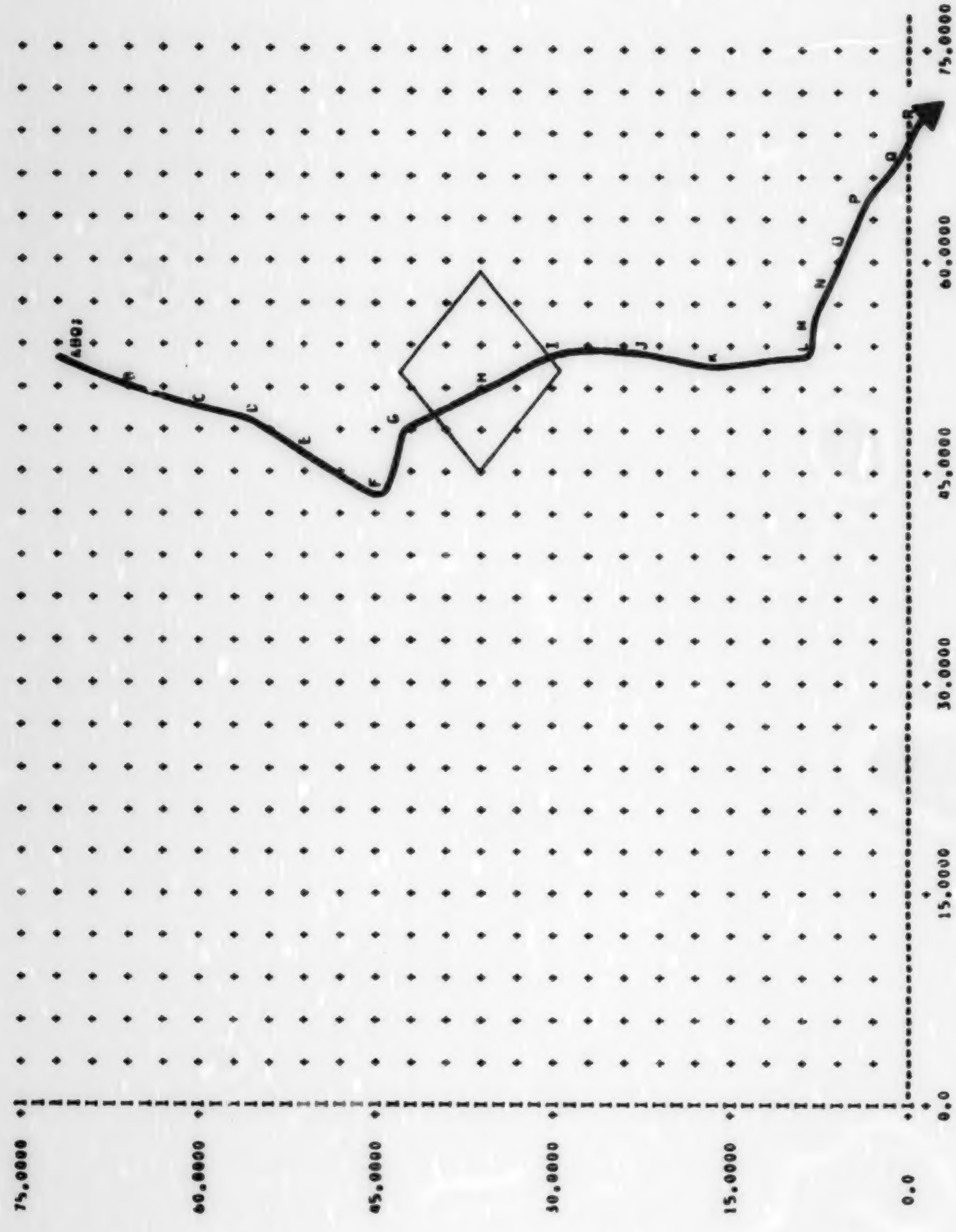

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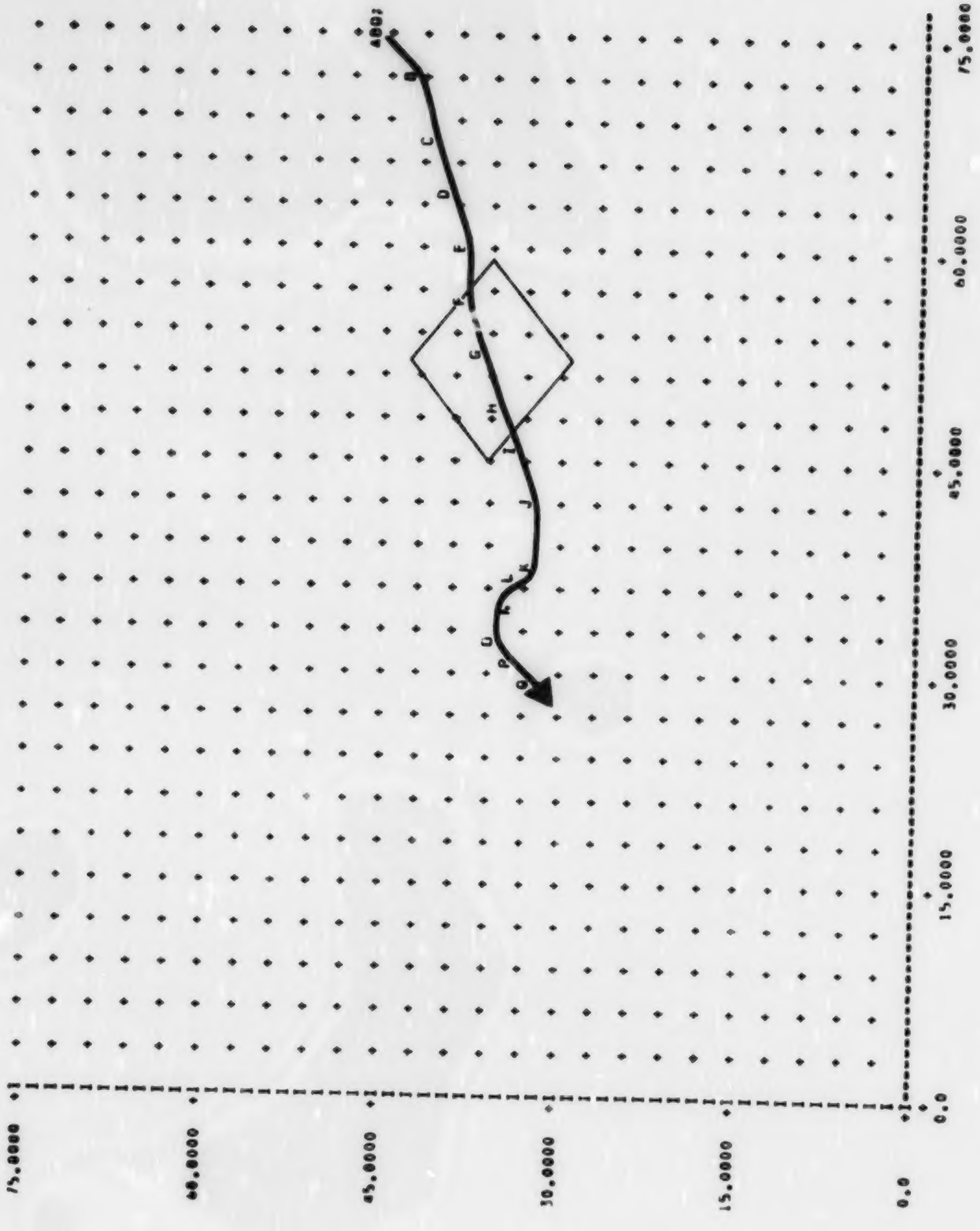

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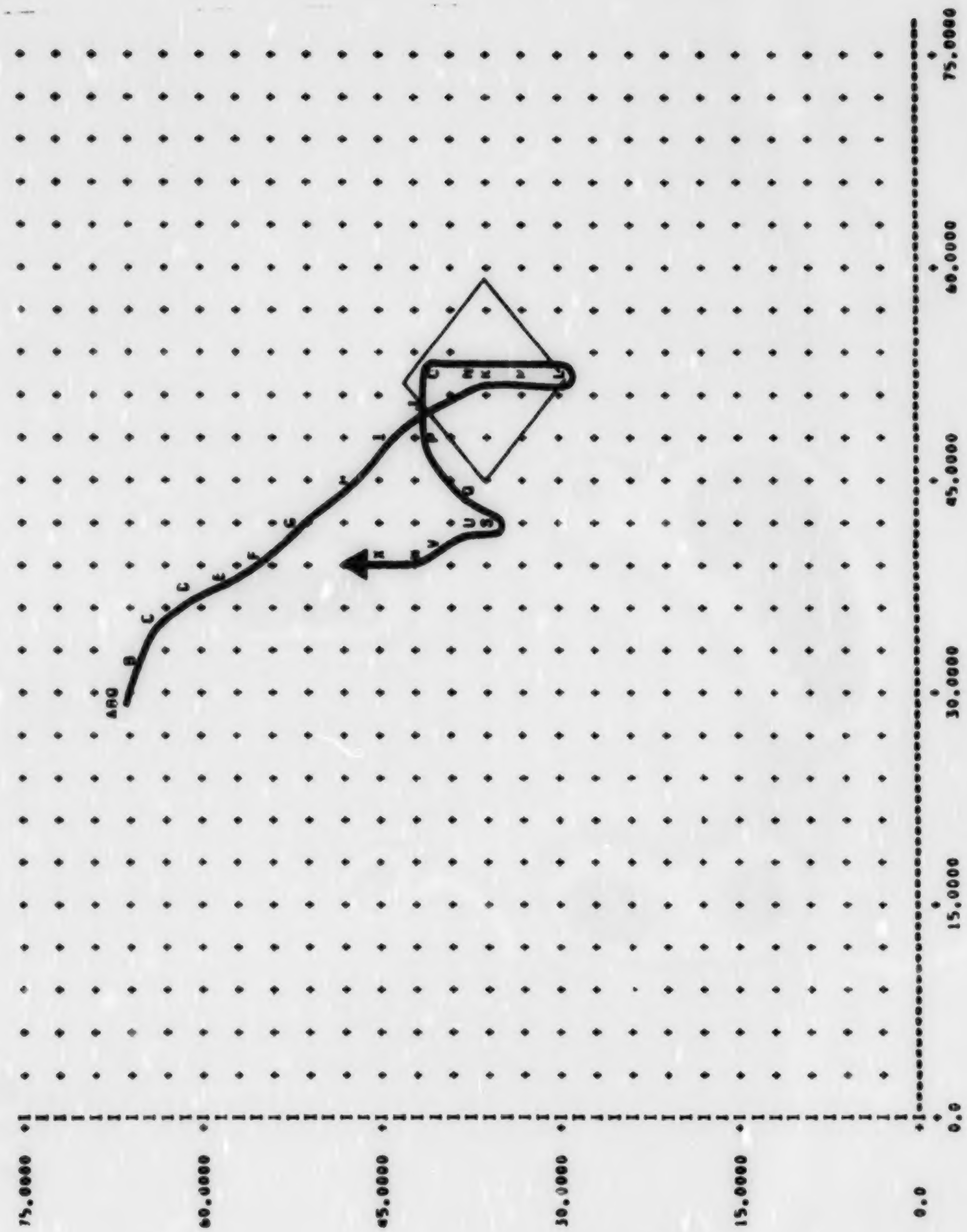

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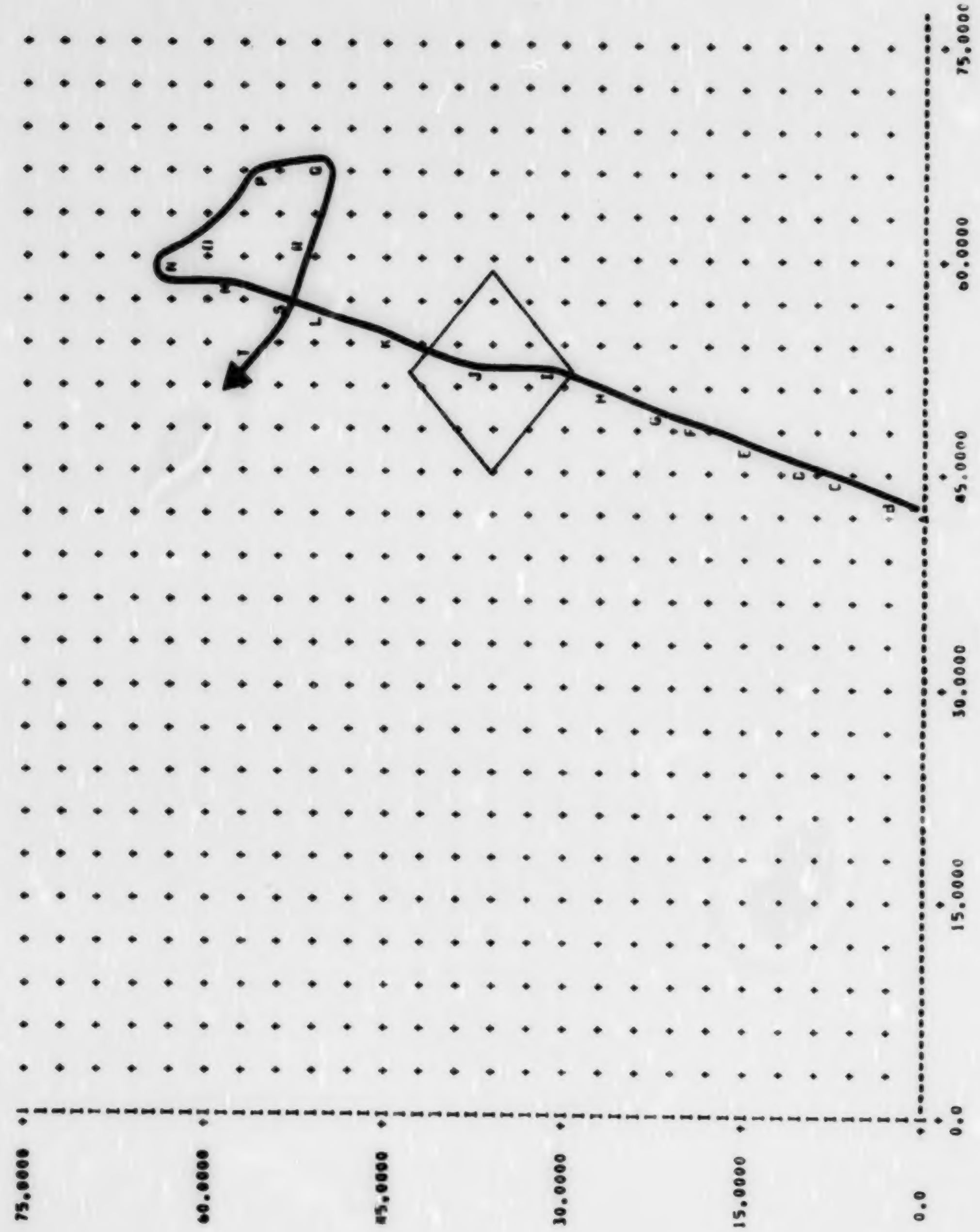

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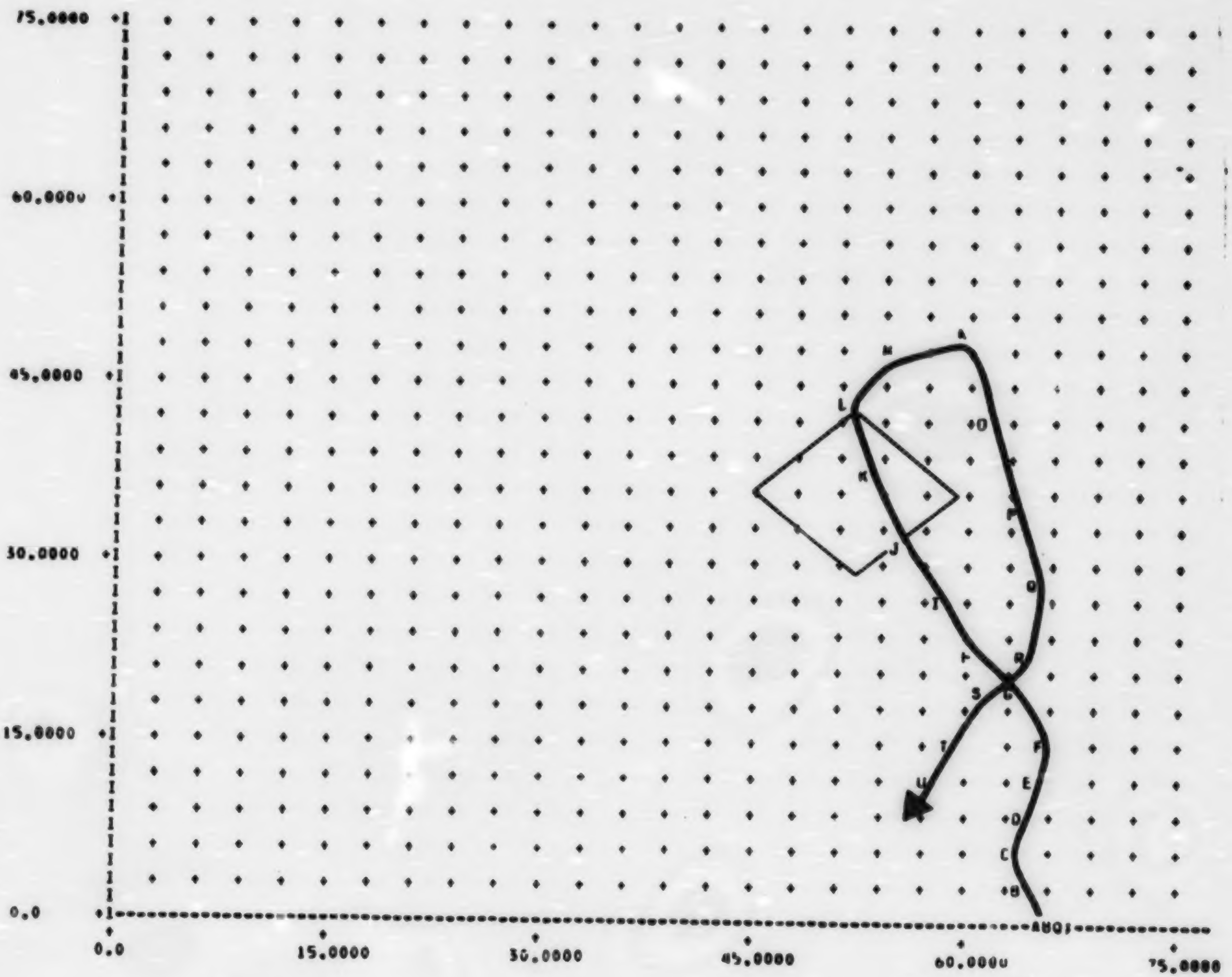

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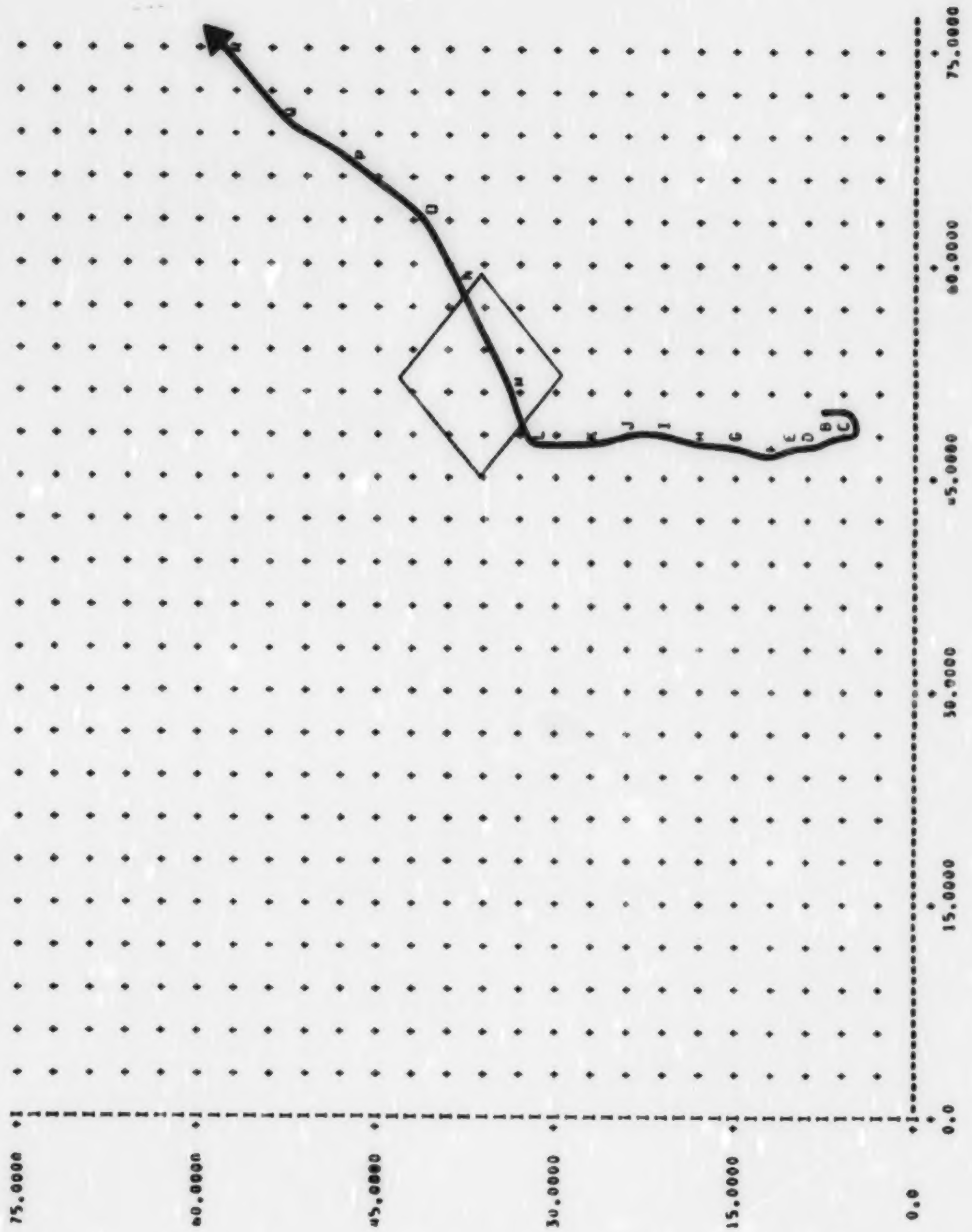

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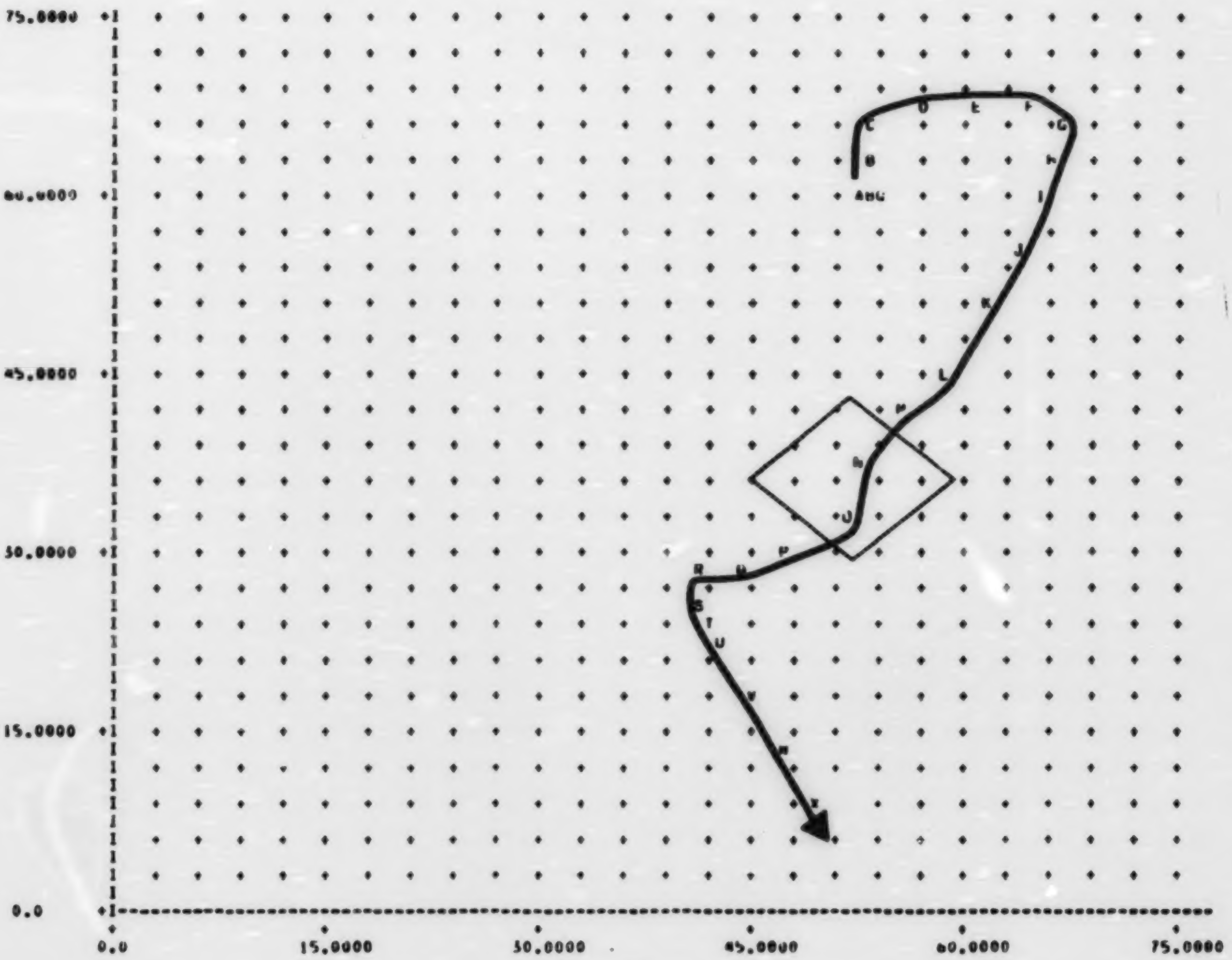

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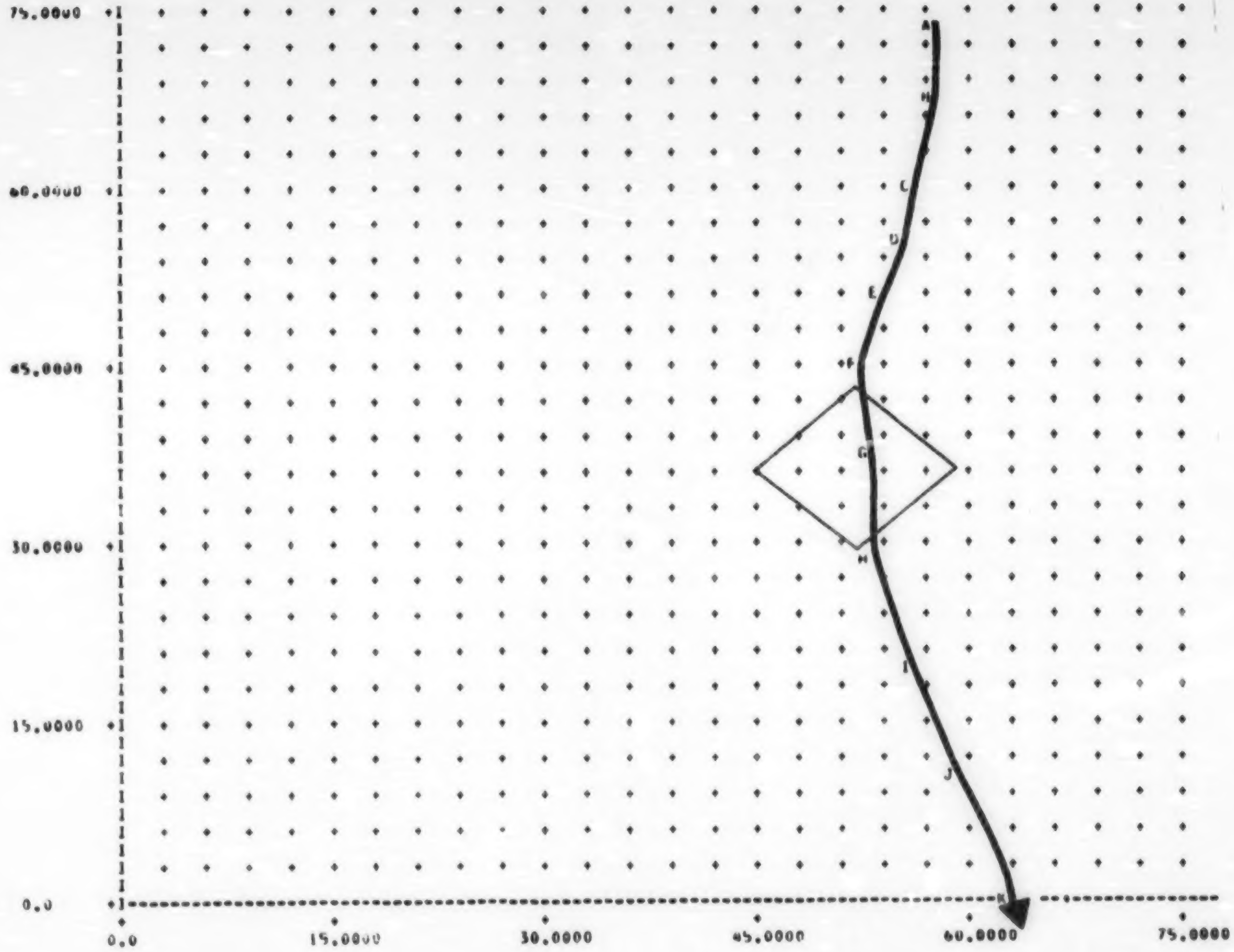

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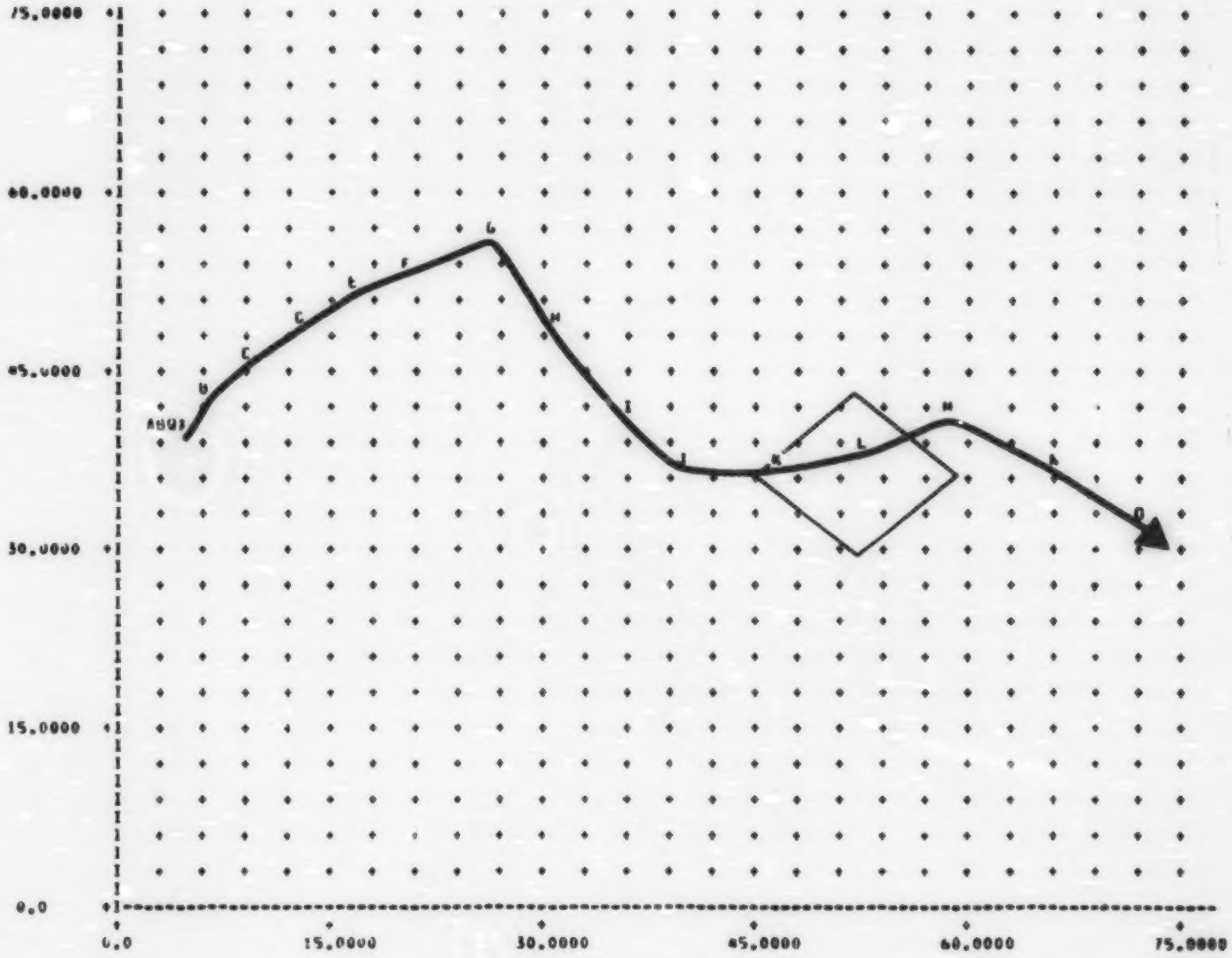

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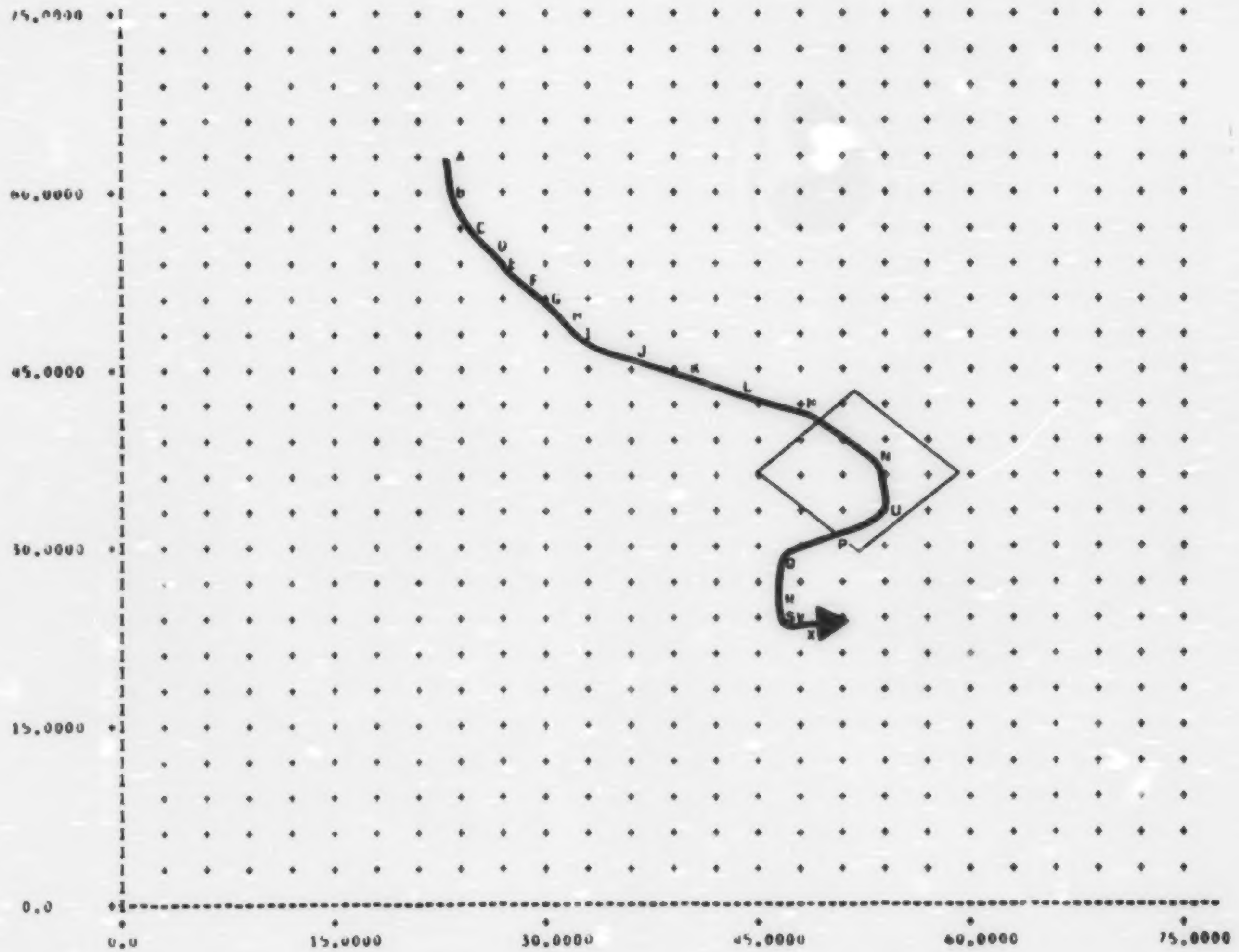

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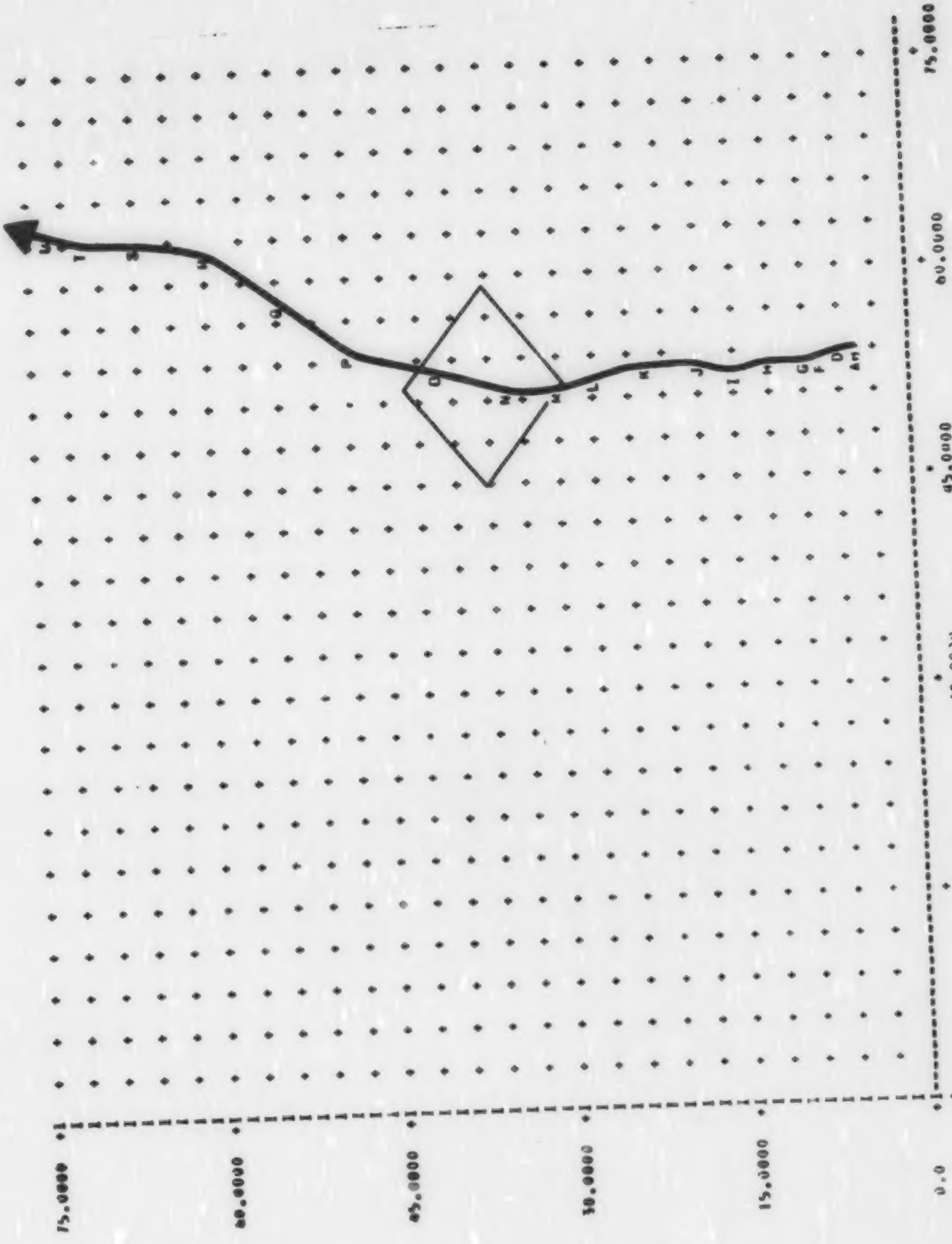
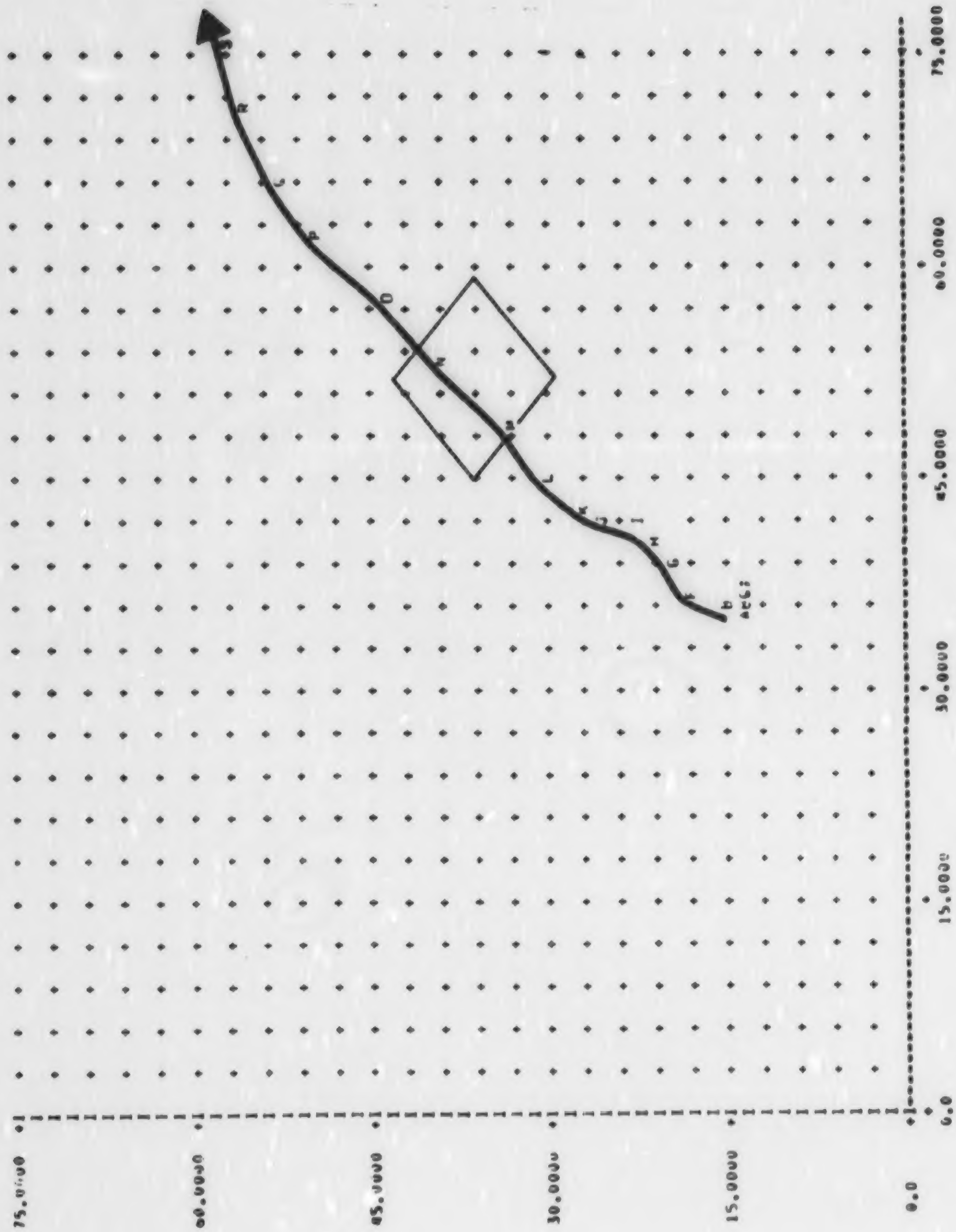


12 August 1976



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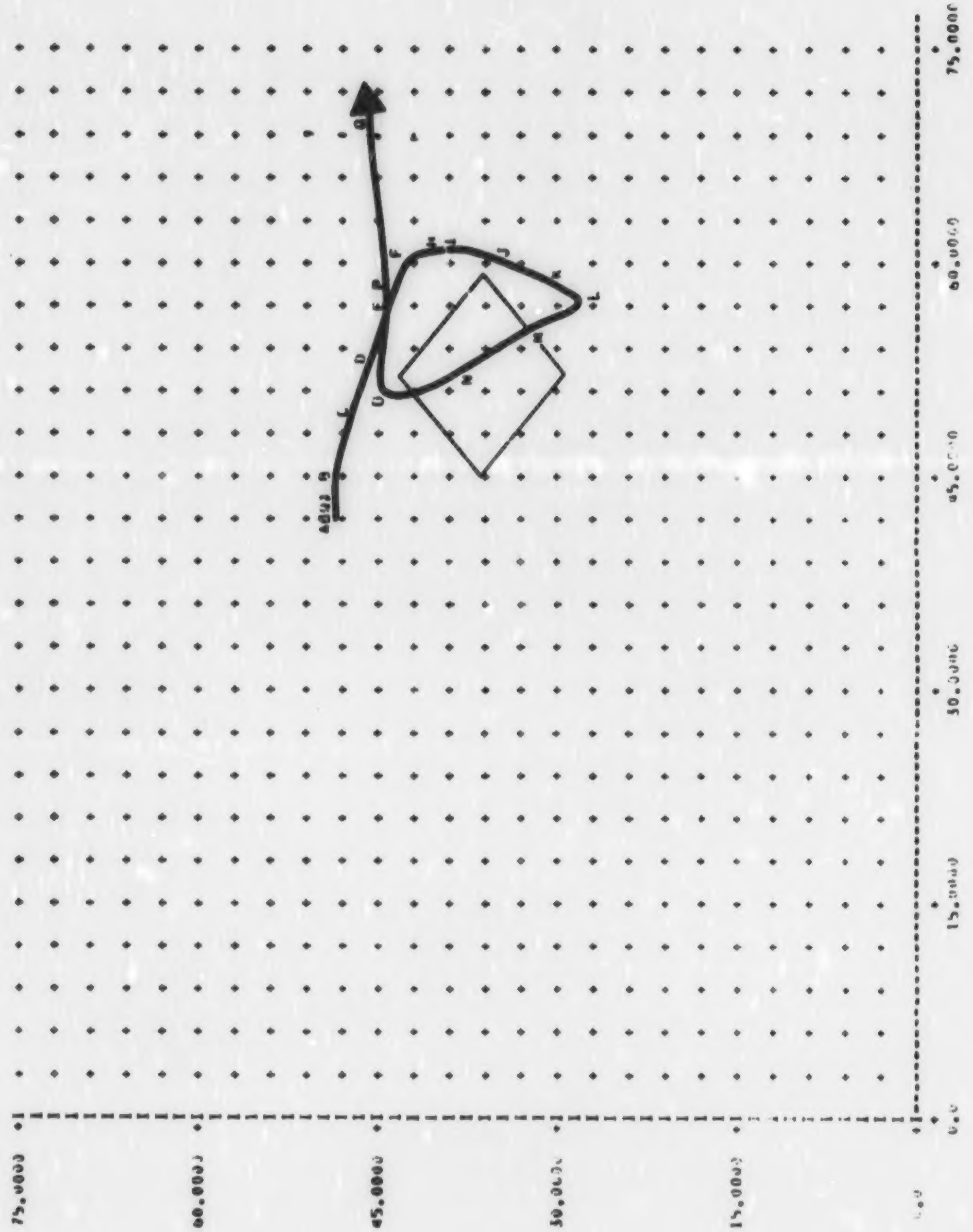

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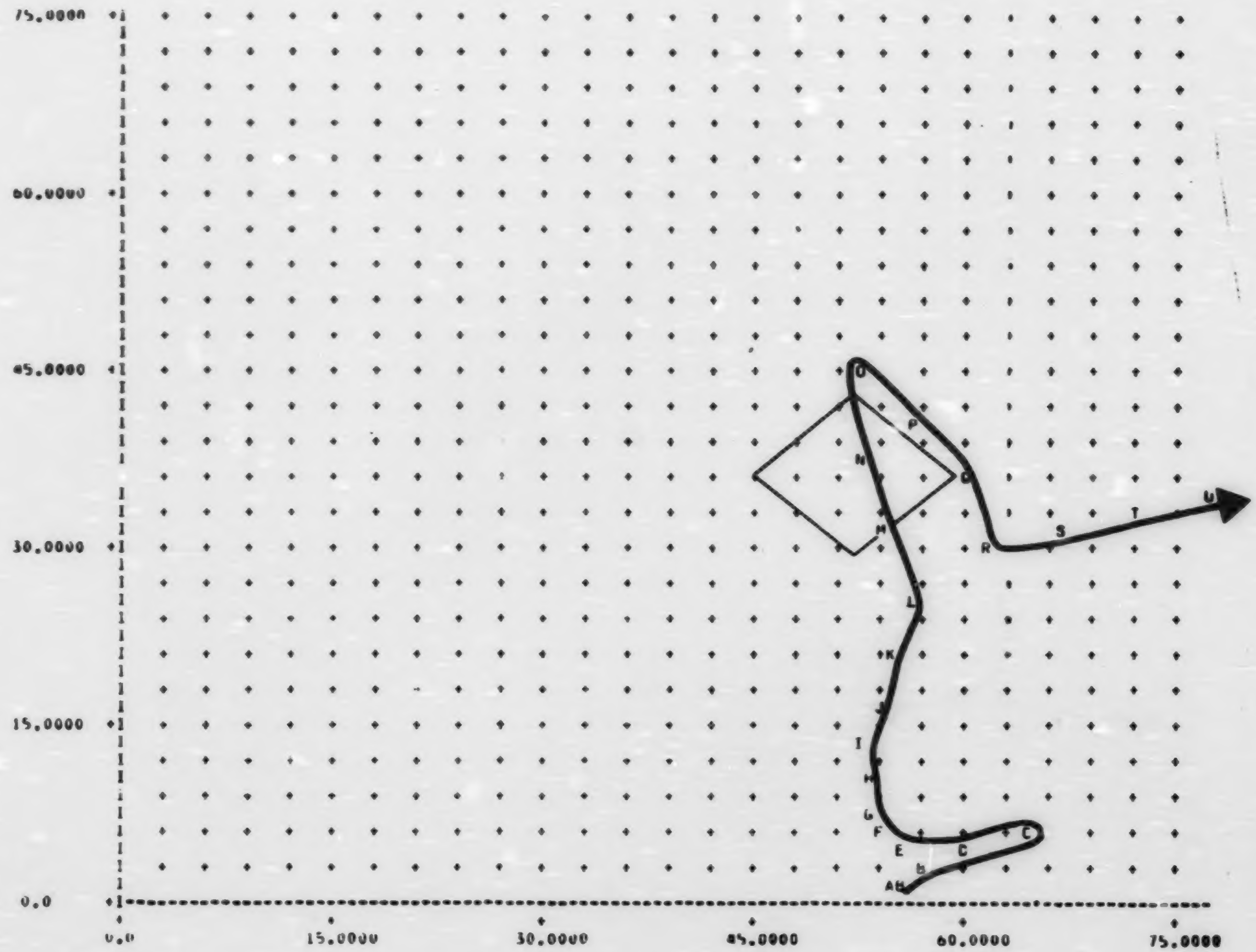

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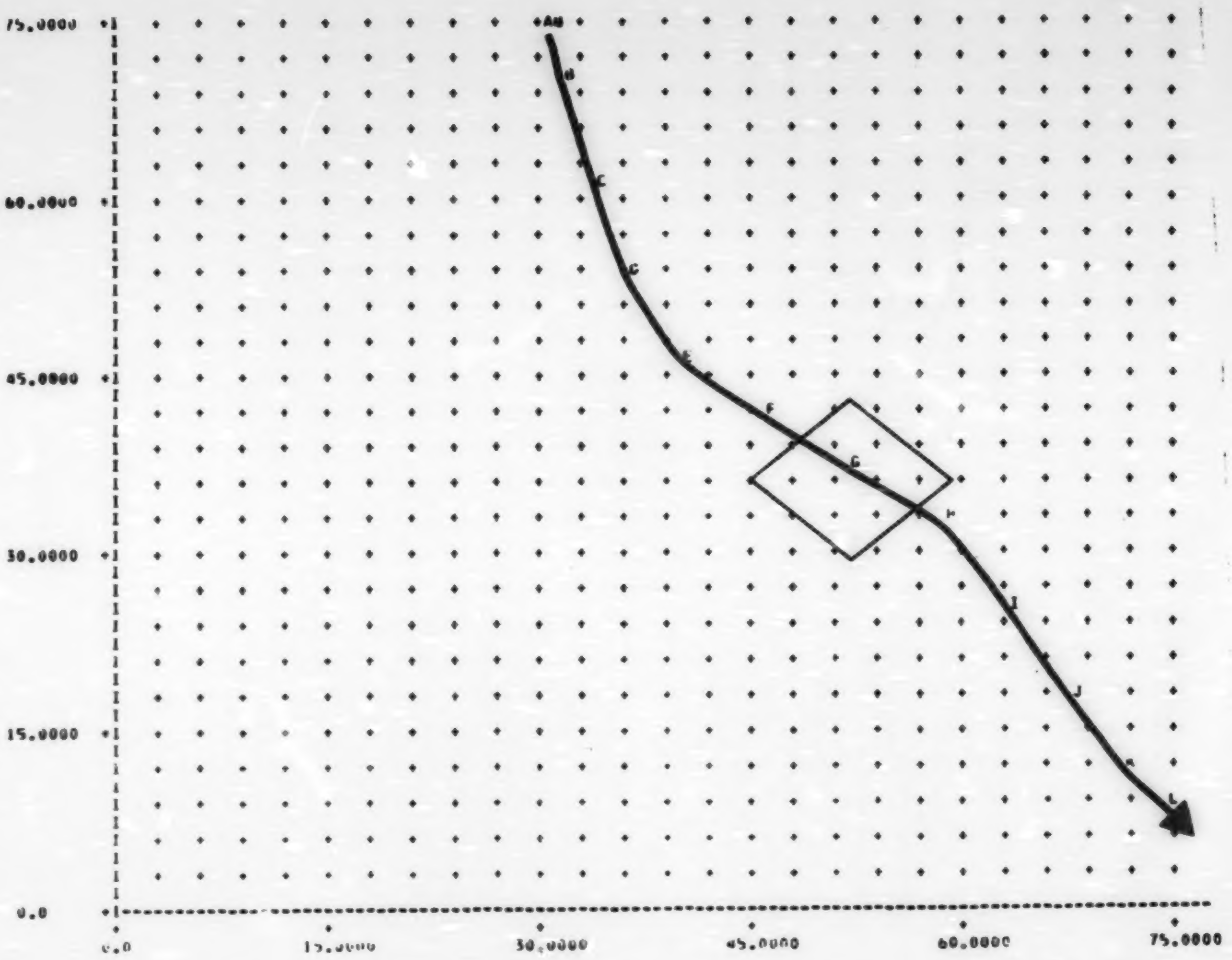

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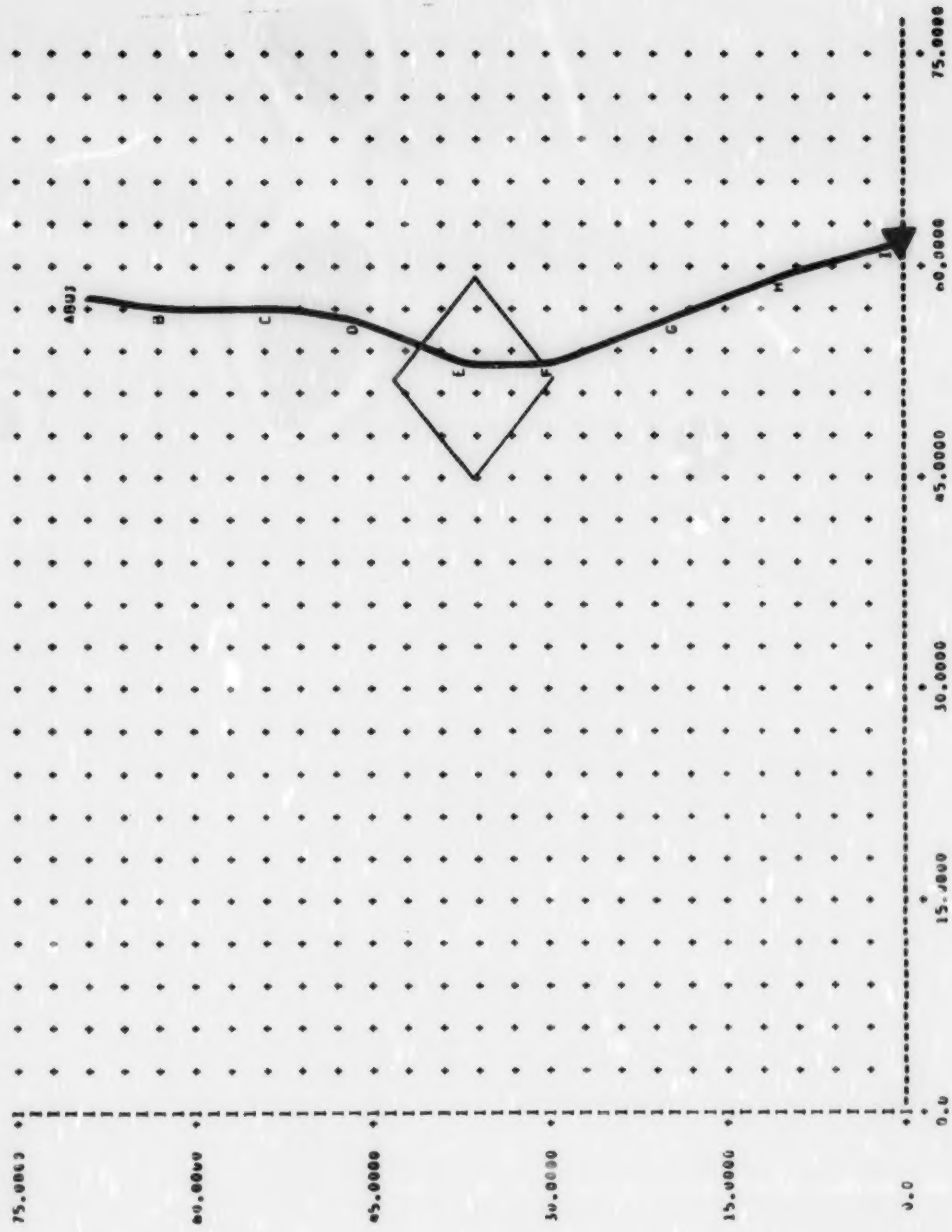

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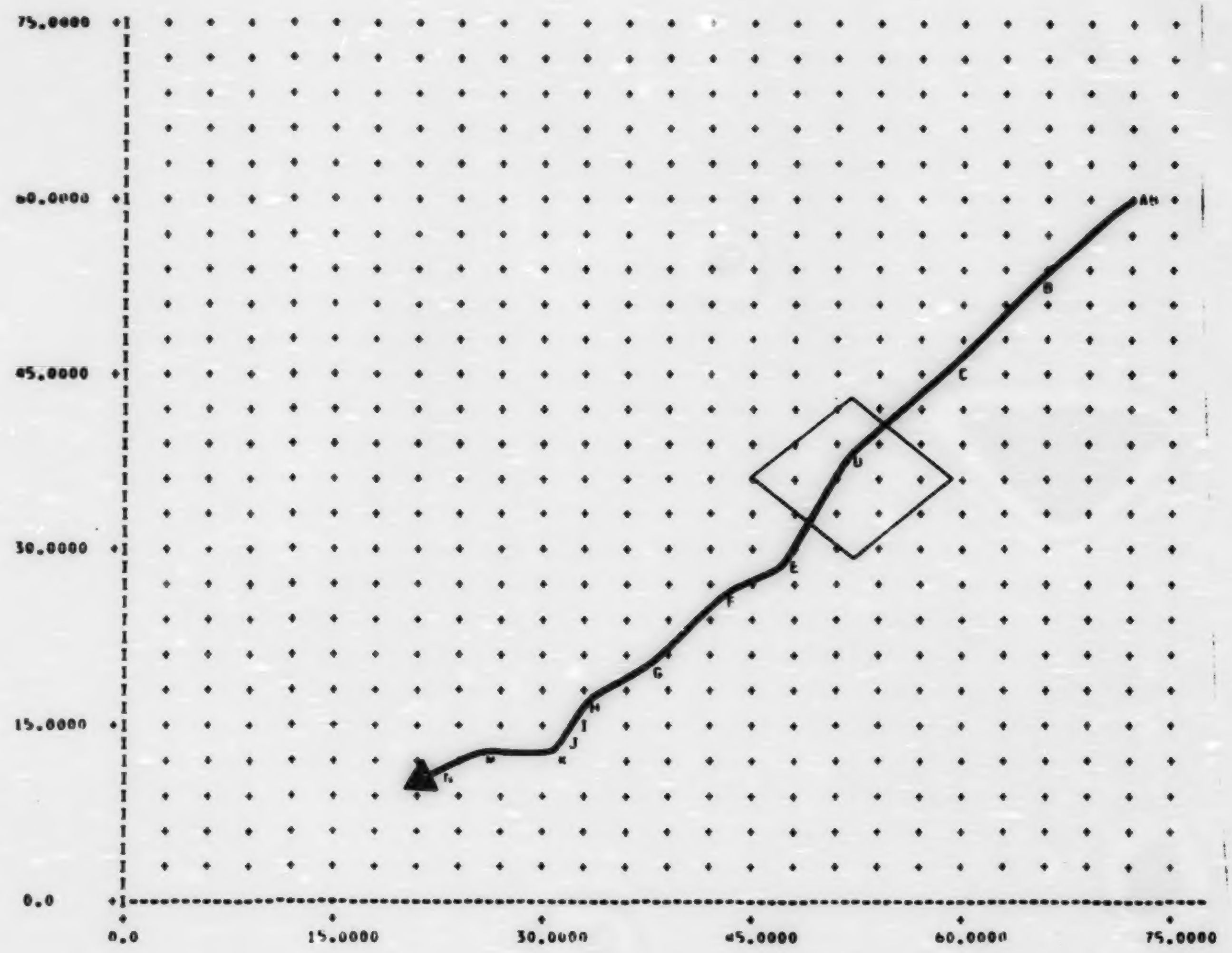

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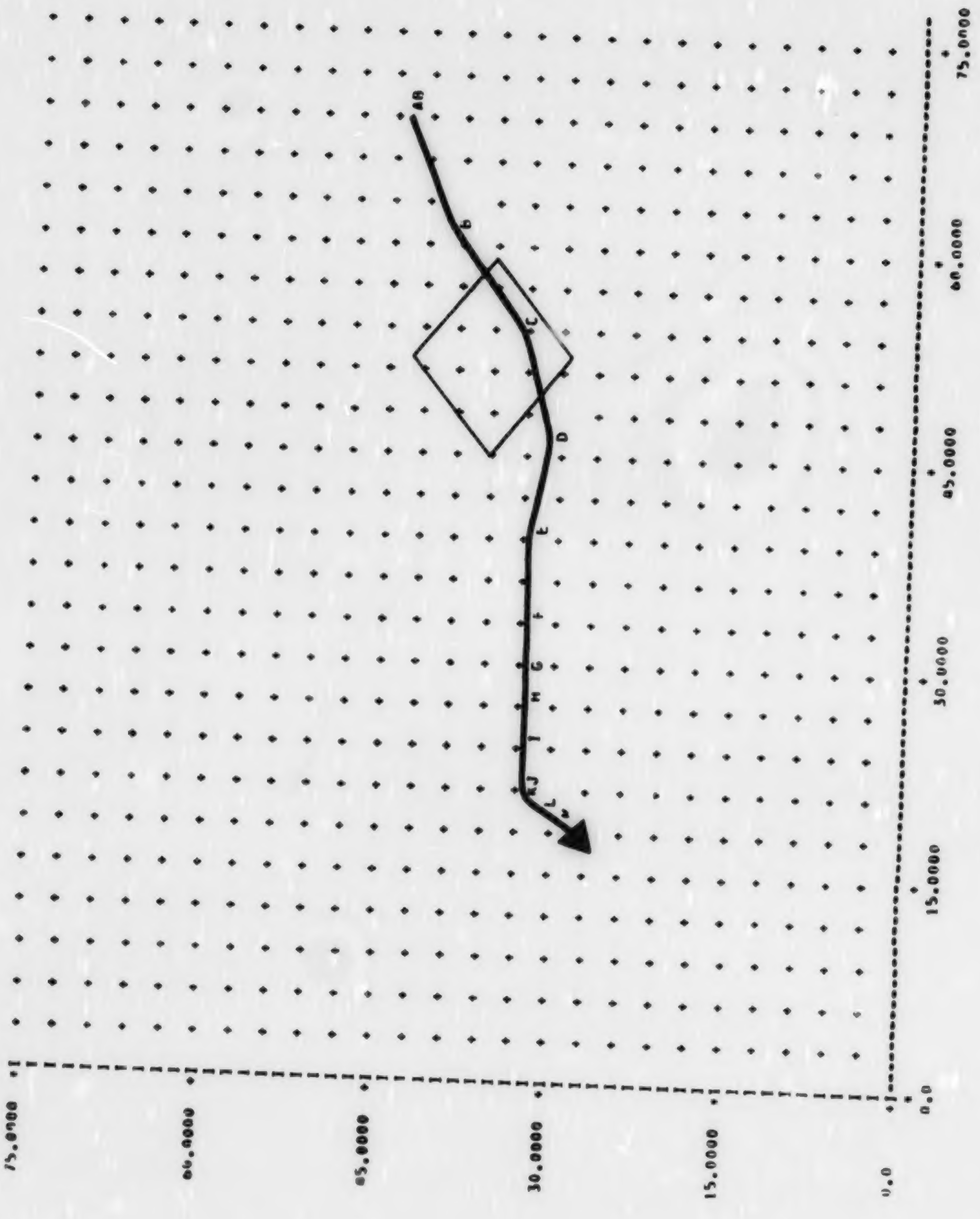

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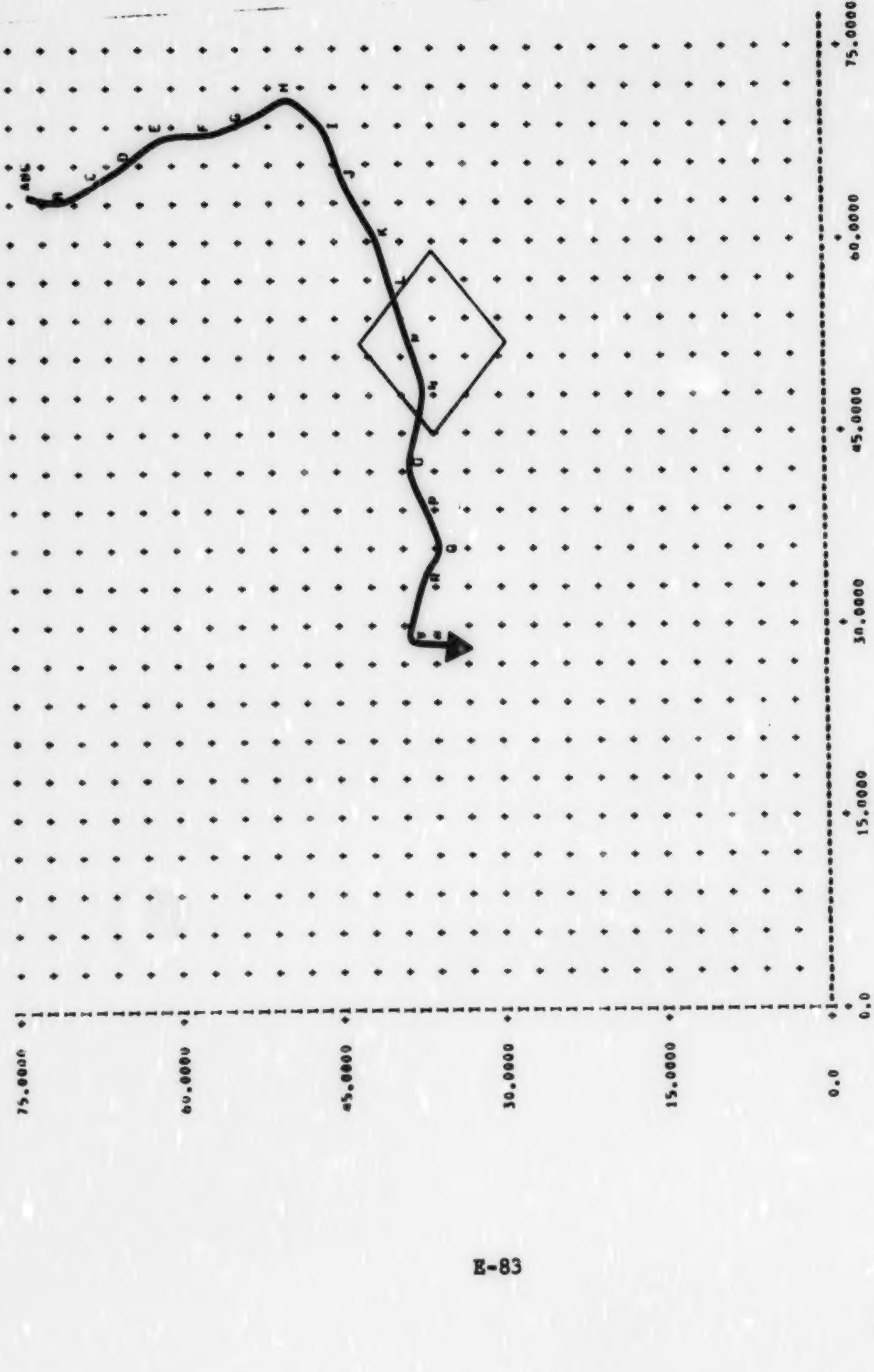

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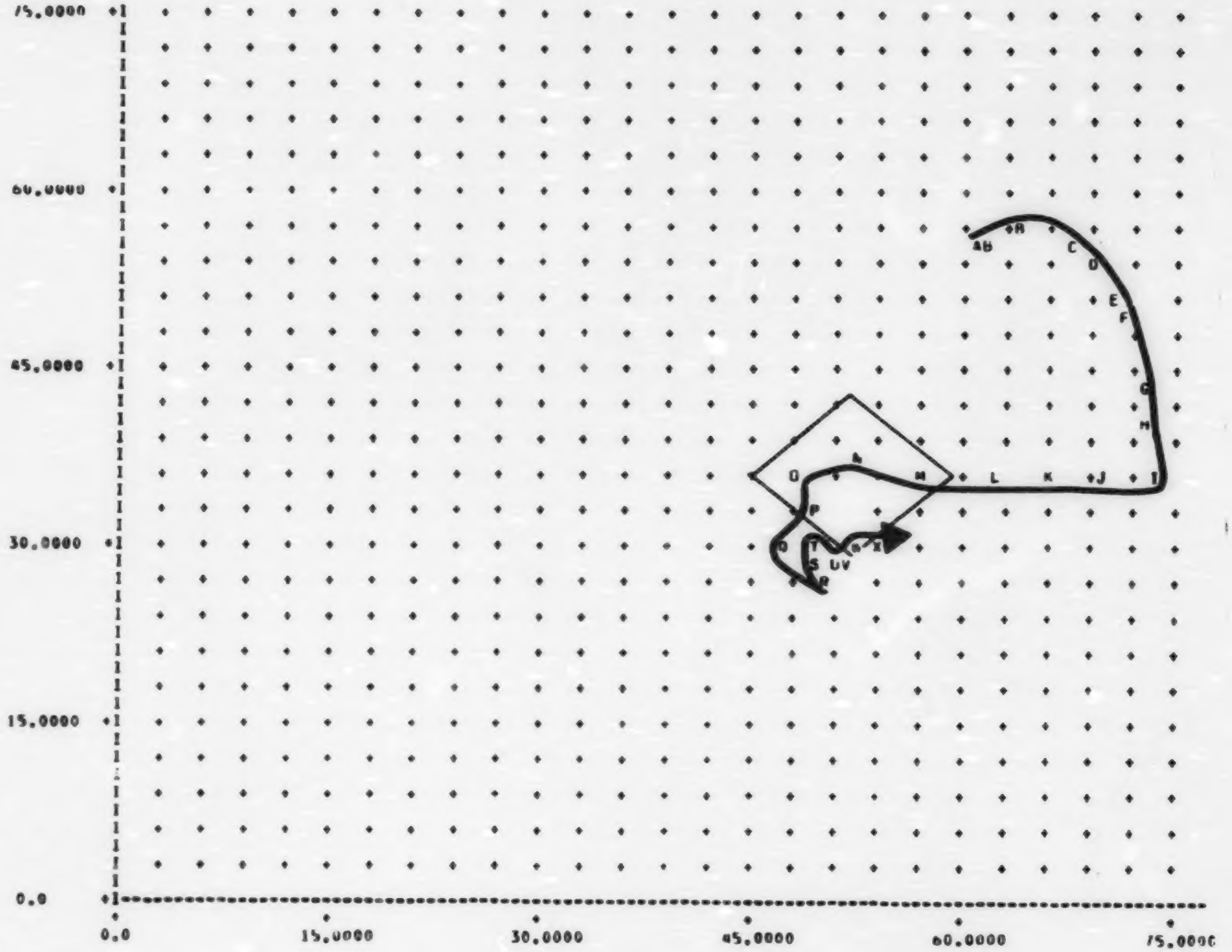

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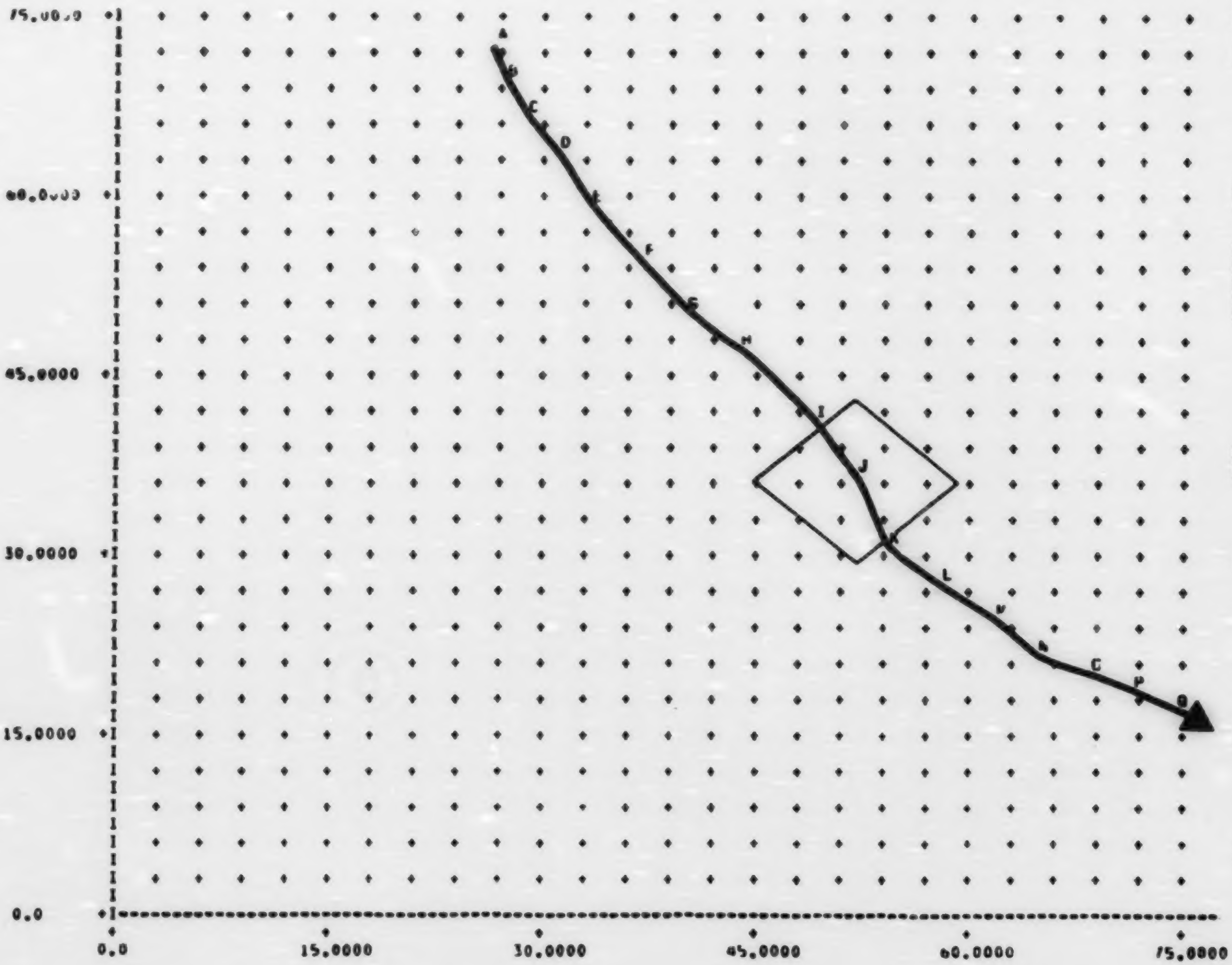

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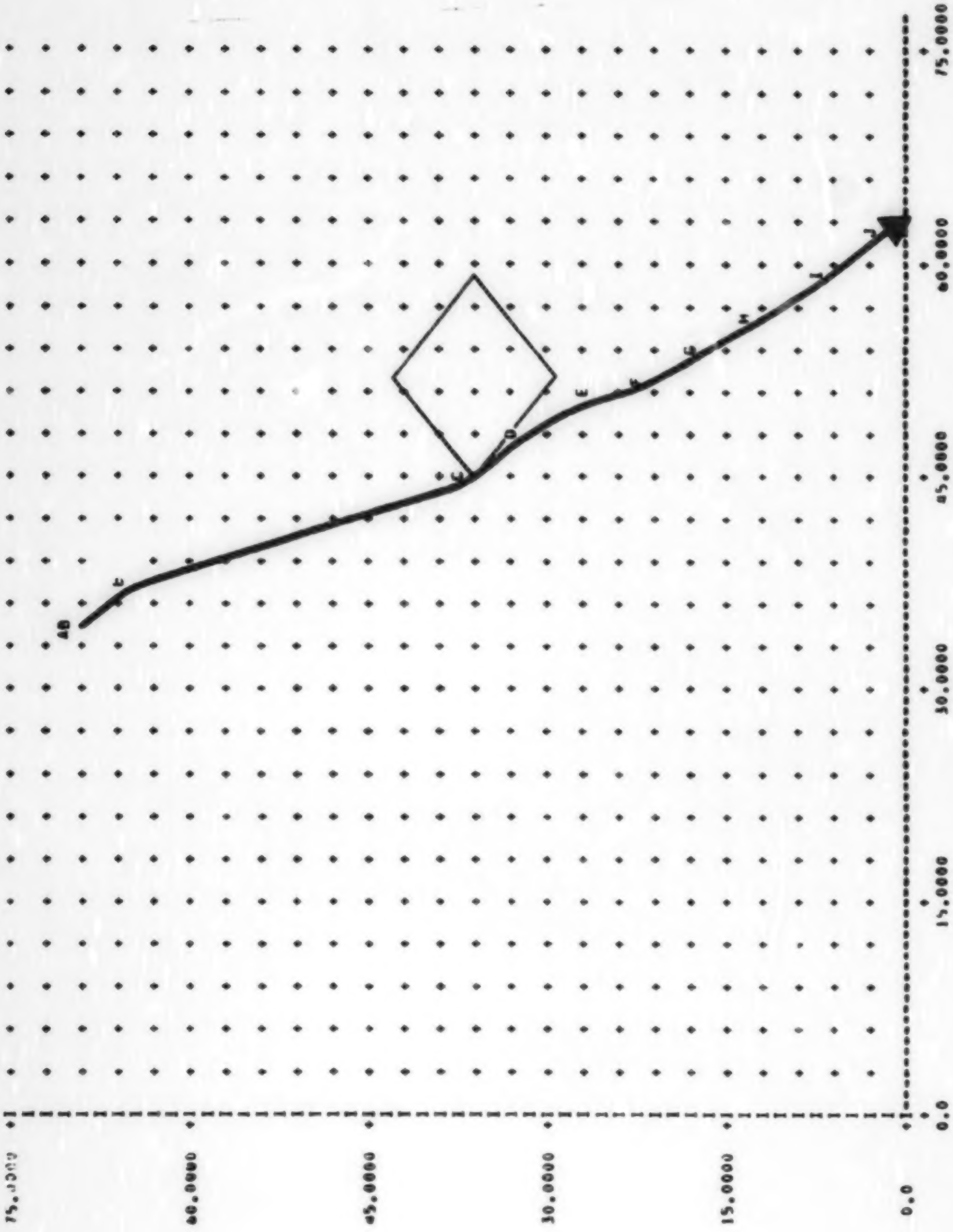

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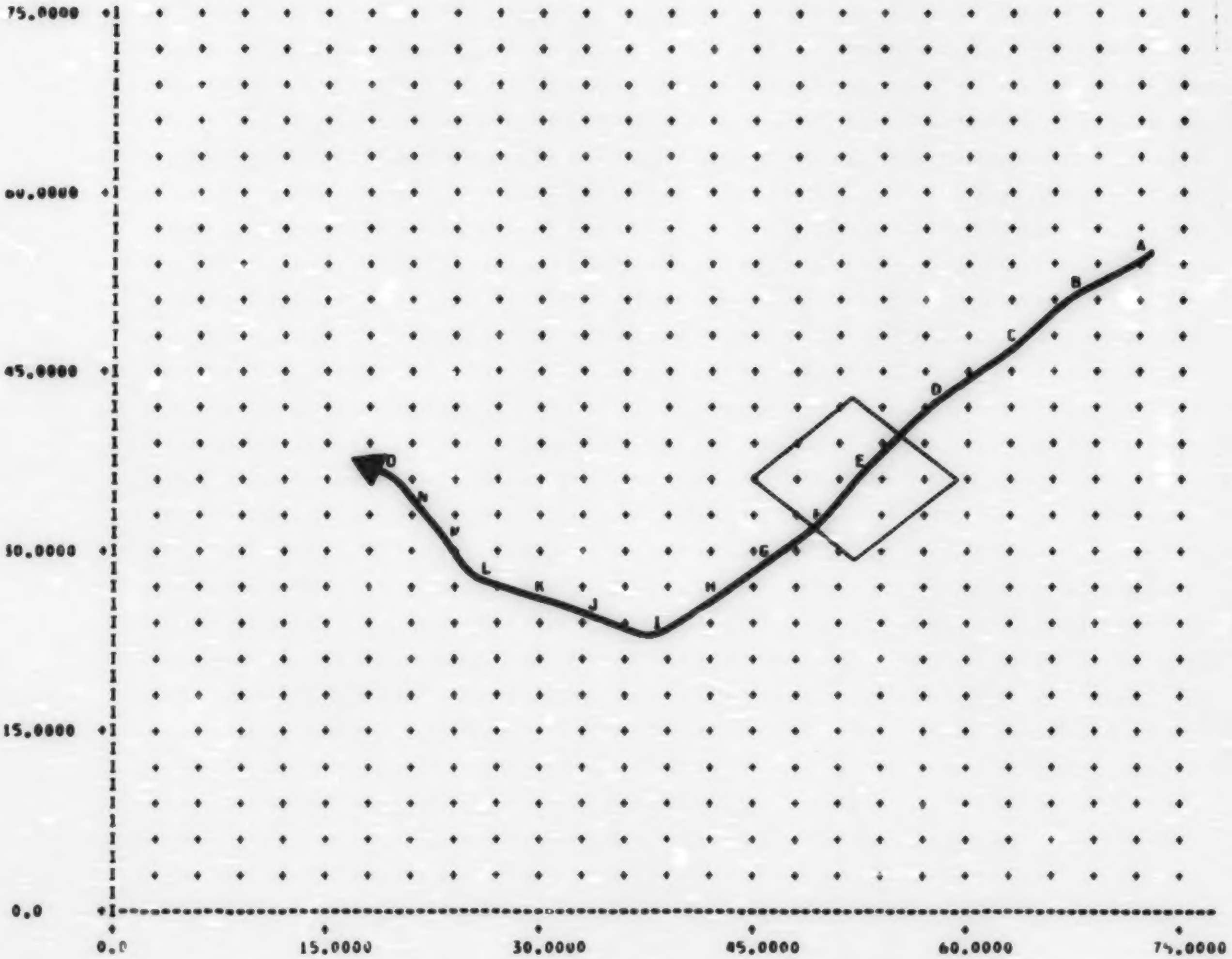

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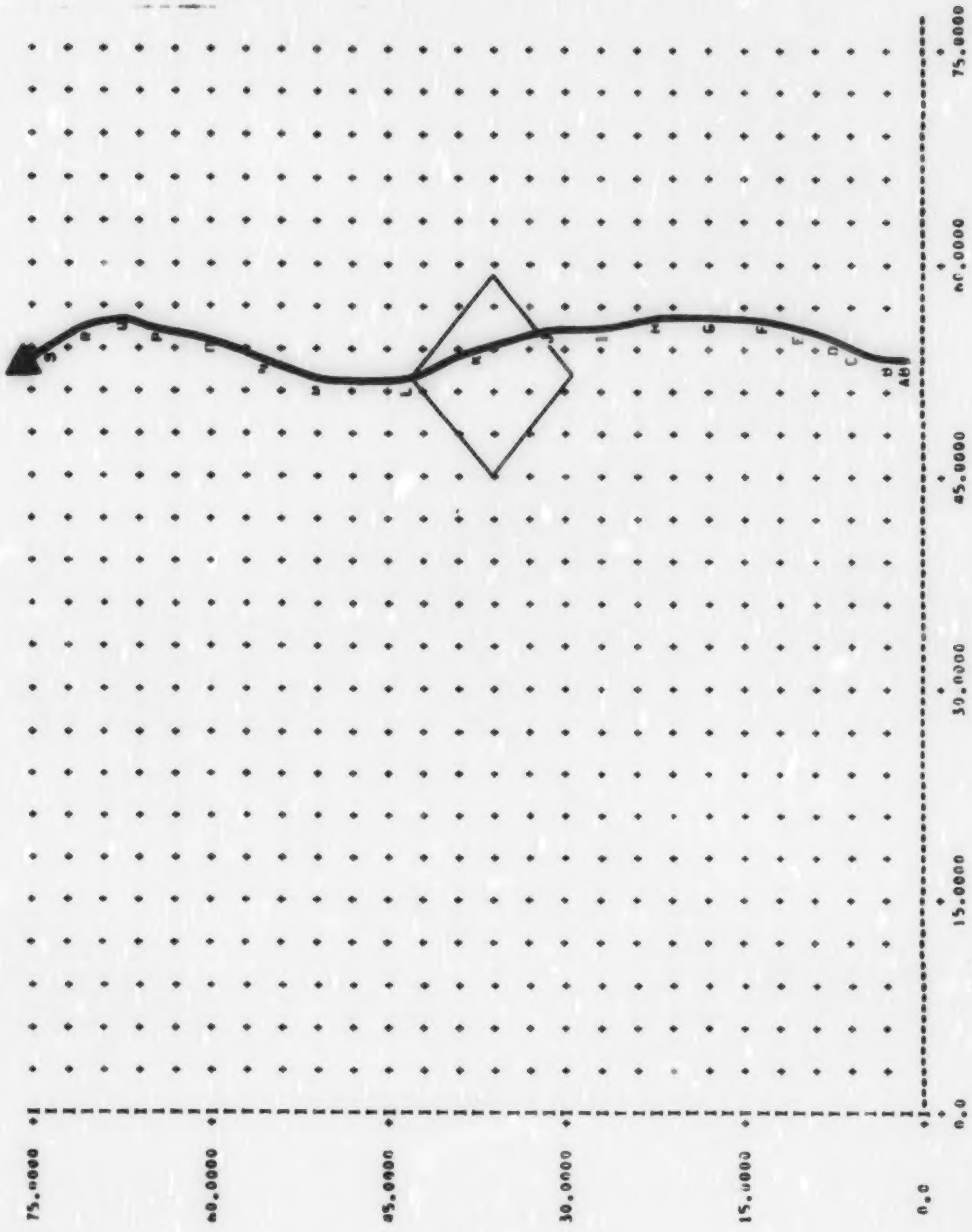
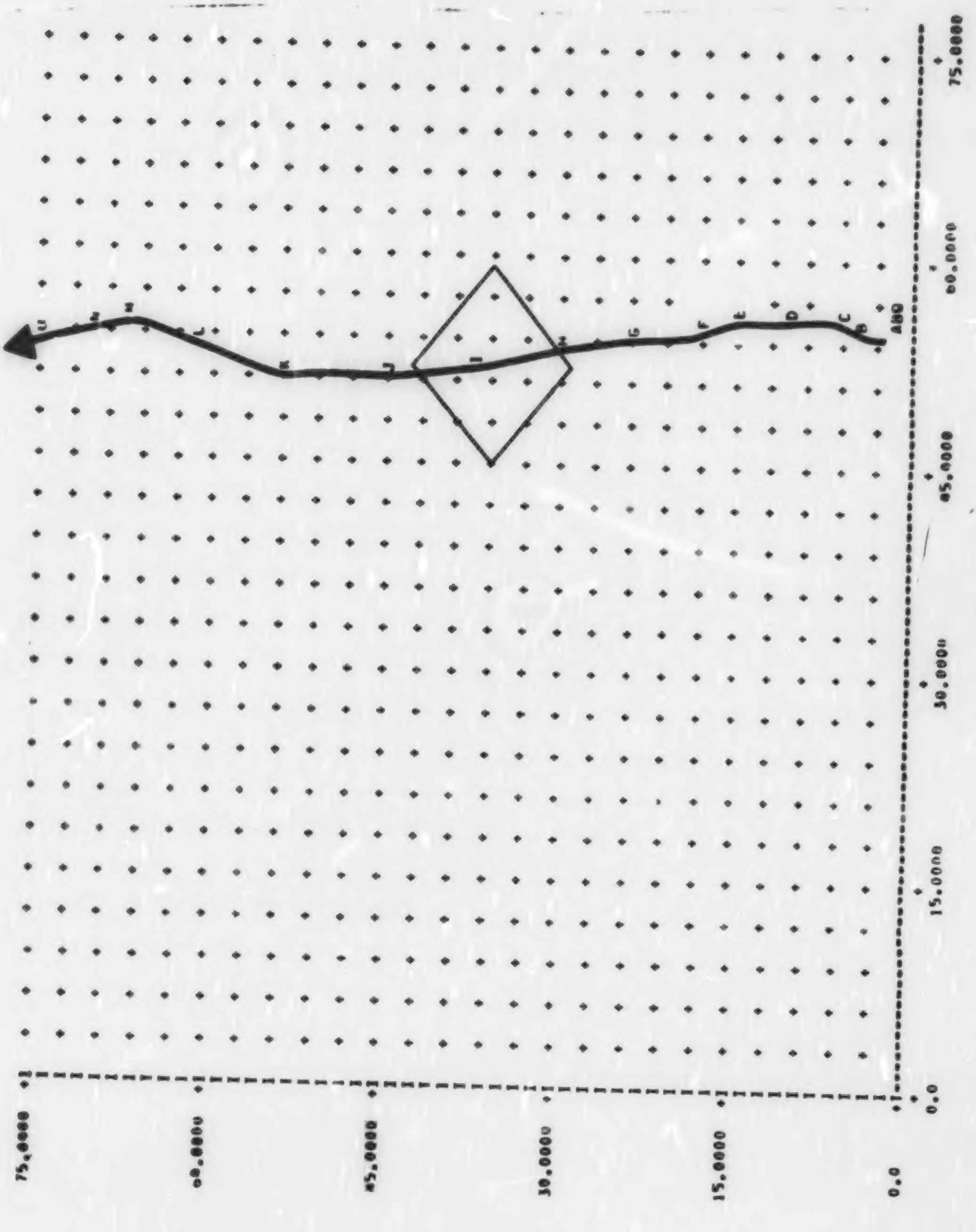
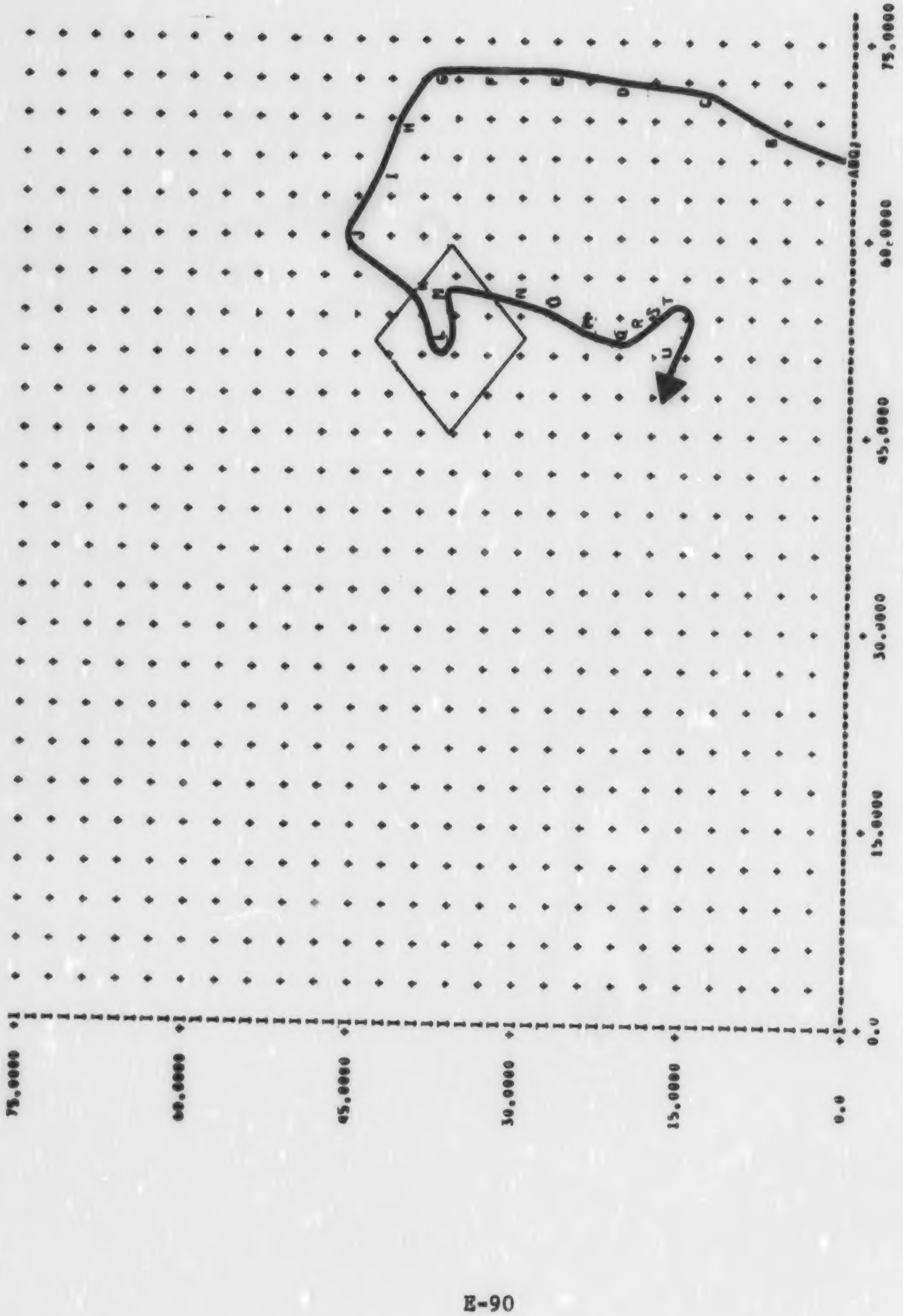


25 August 1976



26 August 1976



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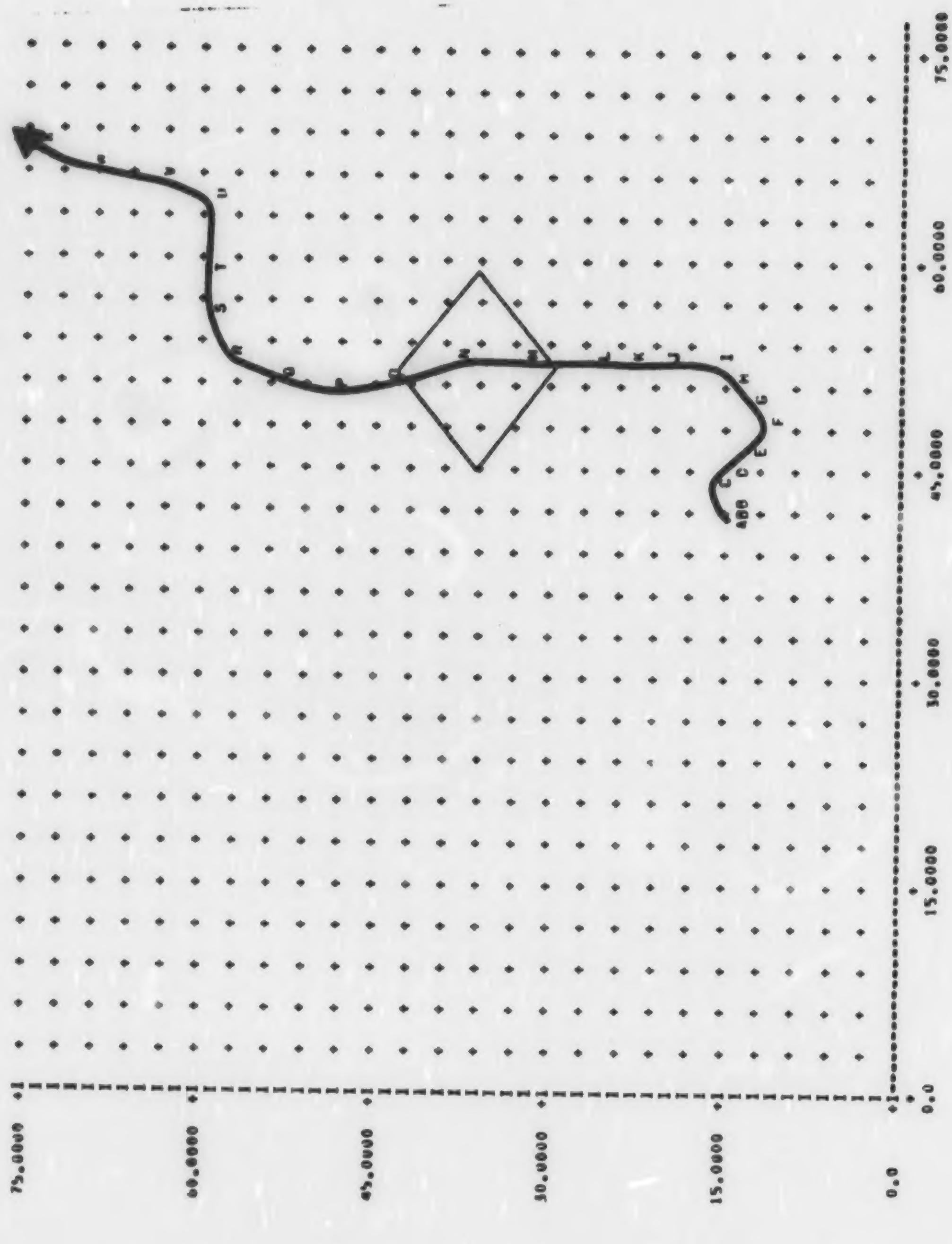
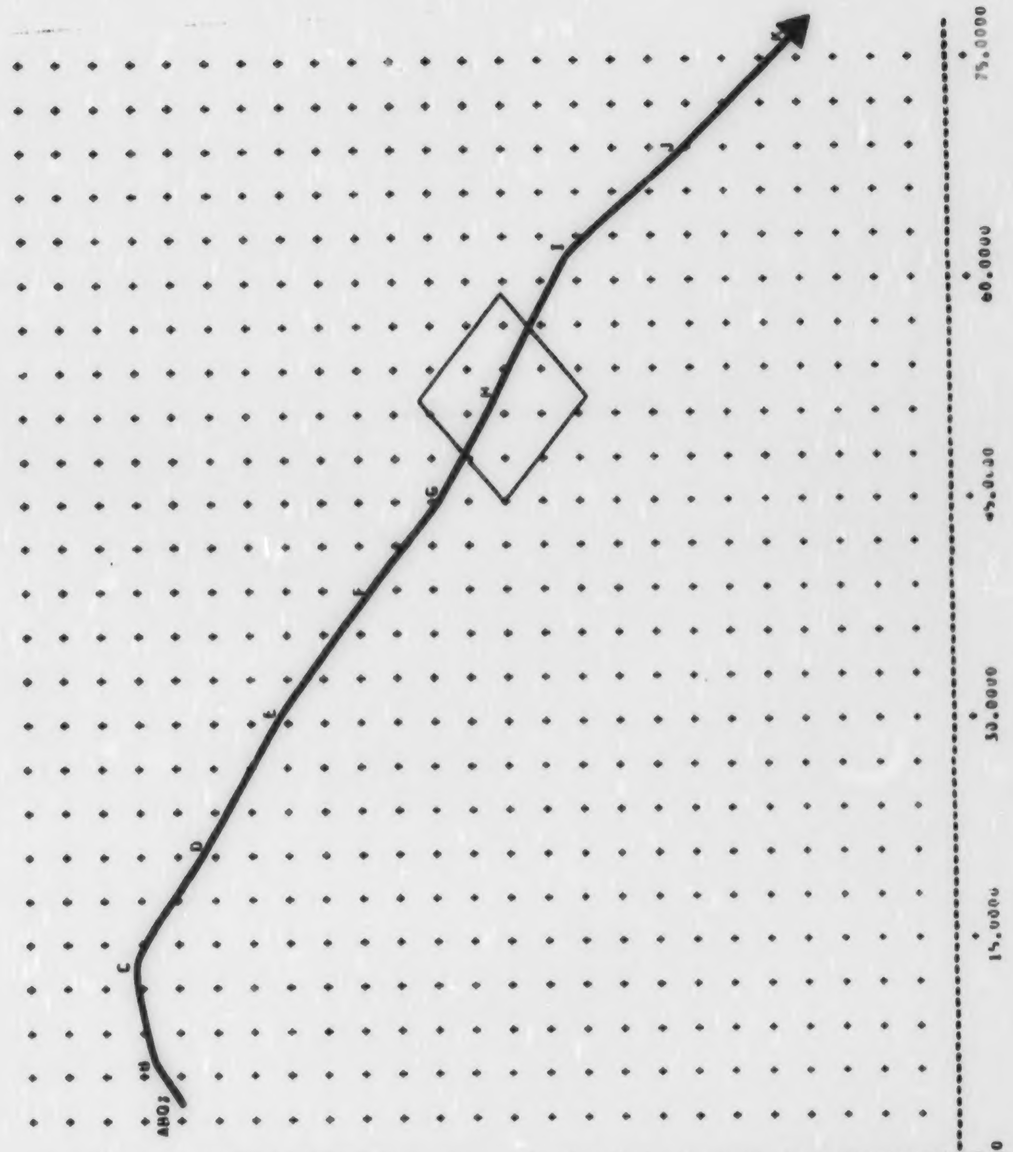


28 August 1976



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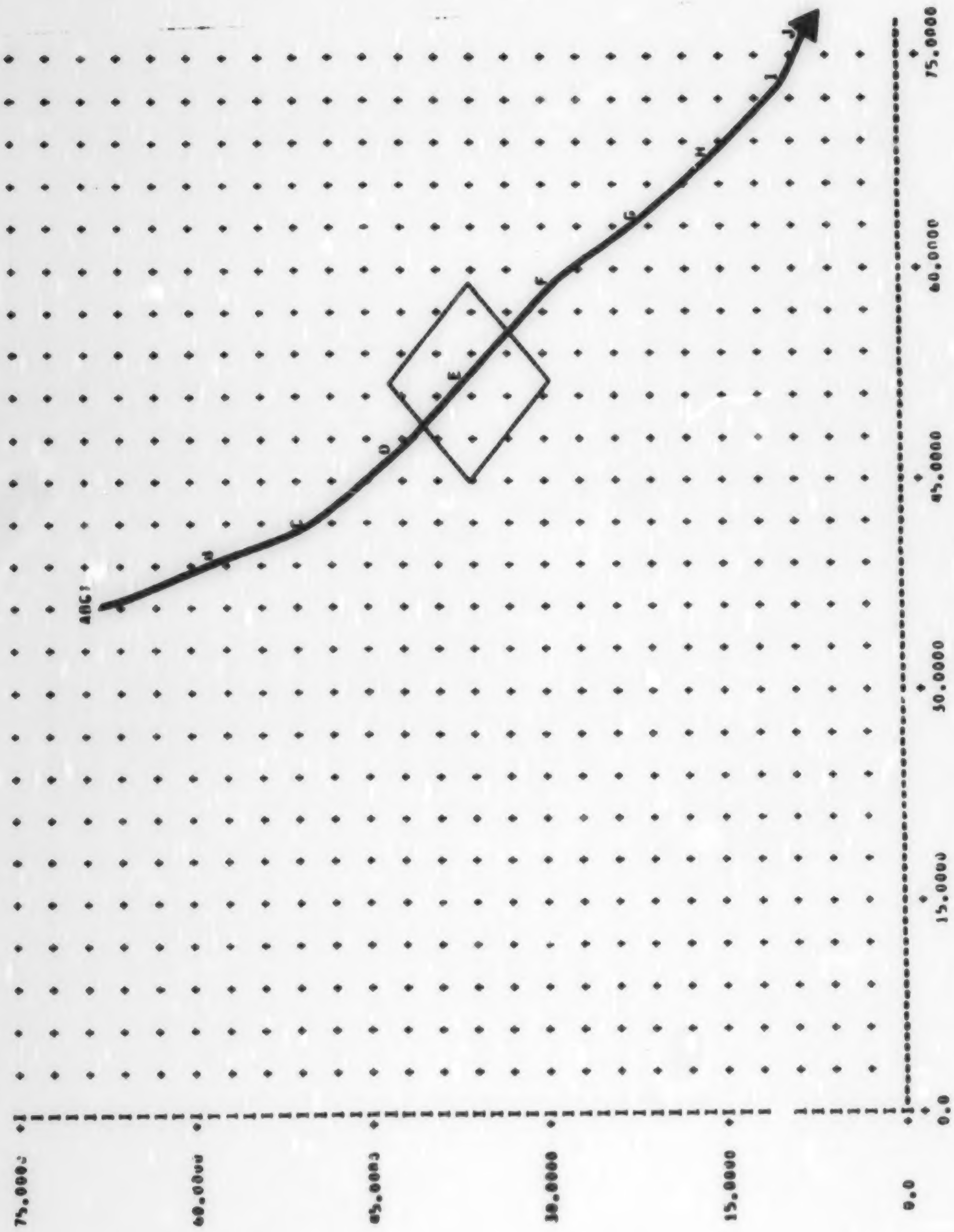
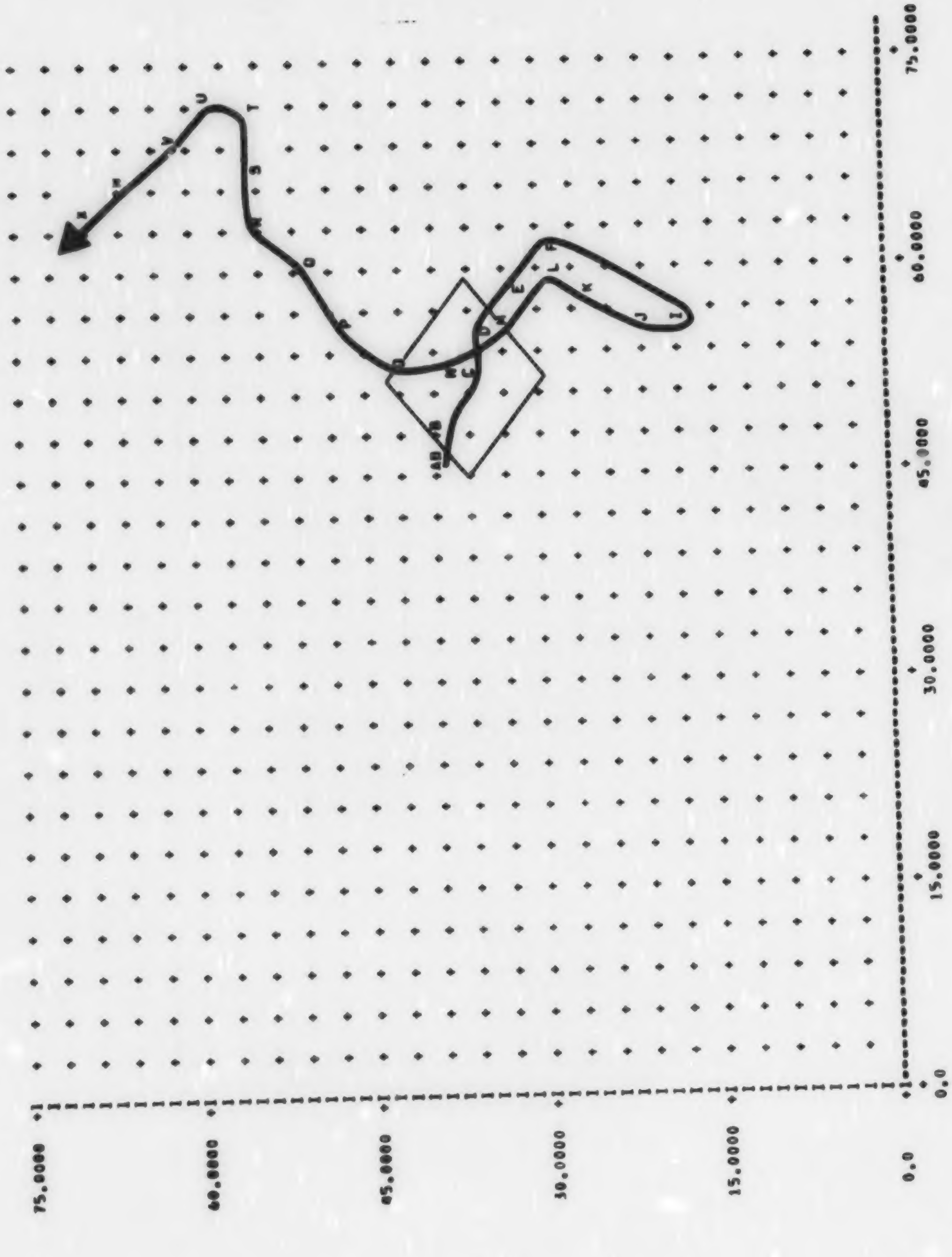


30 August 1976



31 August 1976

APPENDIX F

ADDITIONAL AERIAL SURVEY DATA

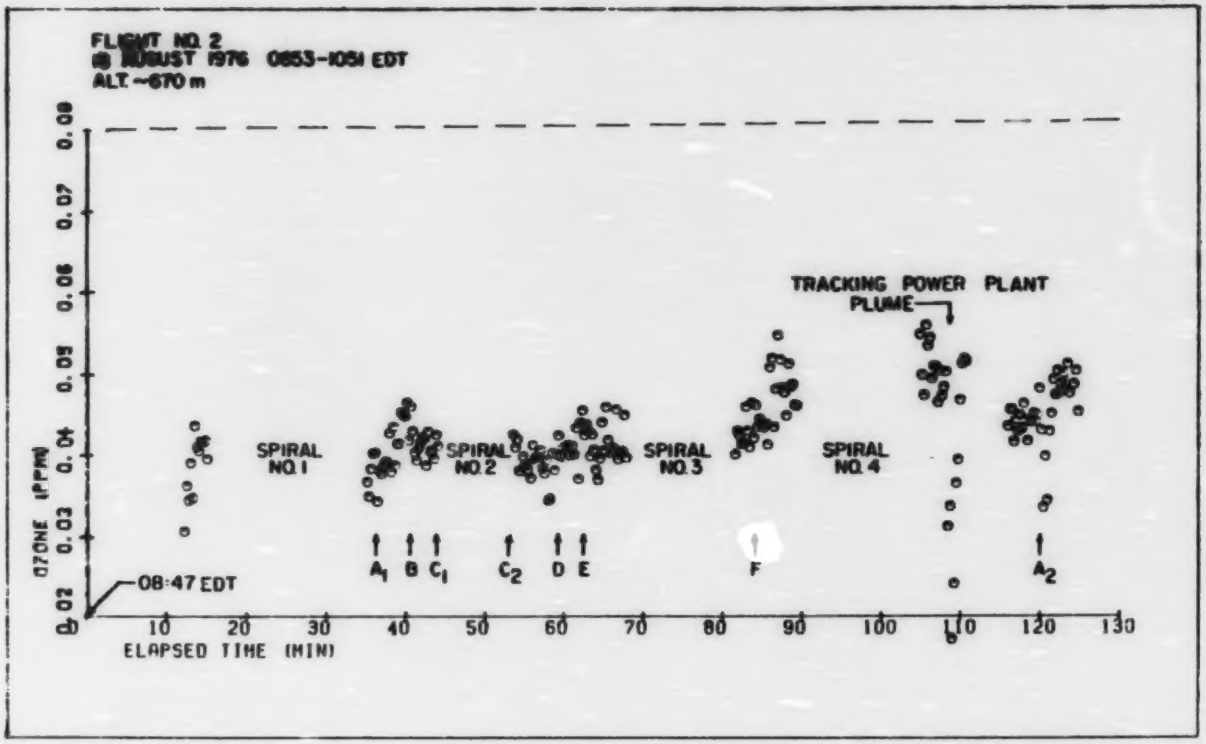


Figure F-1. Ozone concentrations during horizontal sampling, Flight No. 2

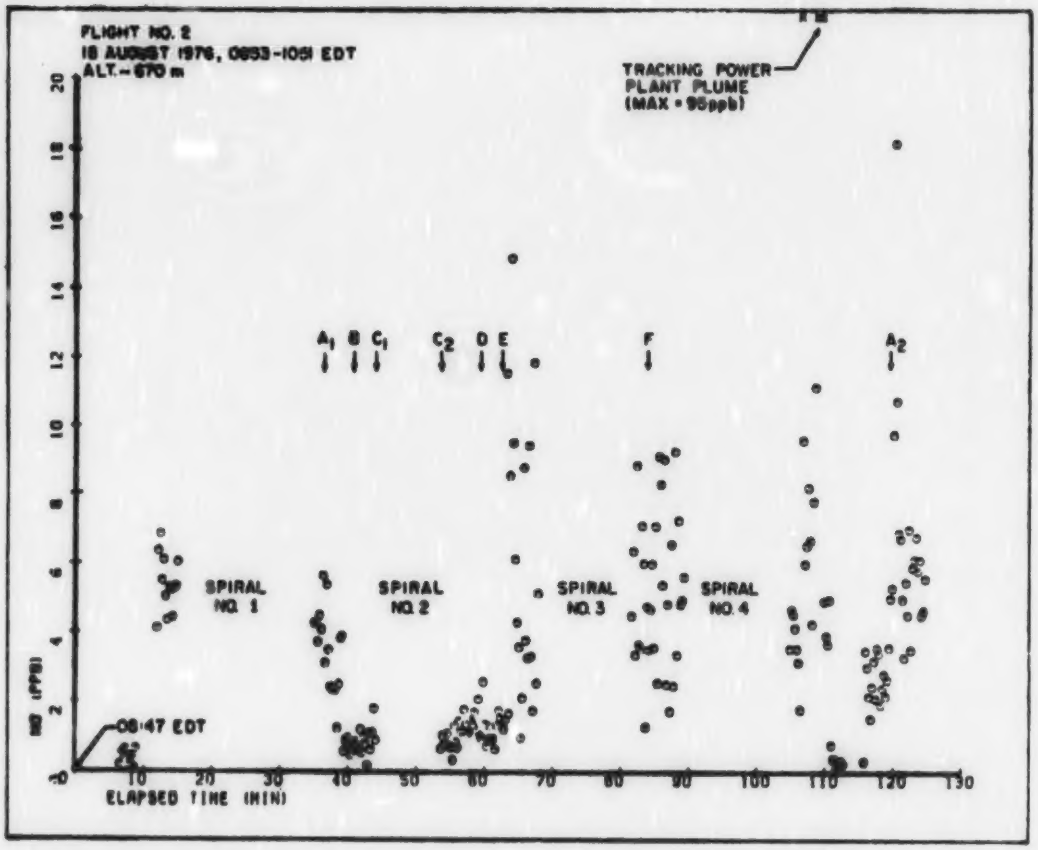


Figure F-2. Nitrogen oxide concentrations during horizontal sampling, Flight No. 2

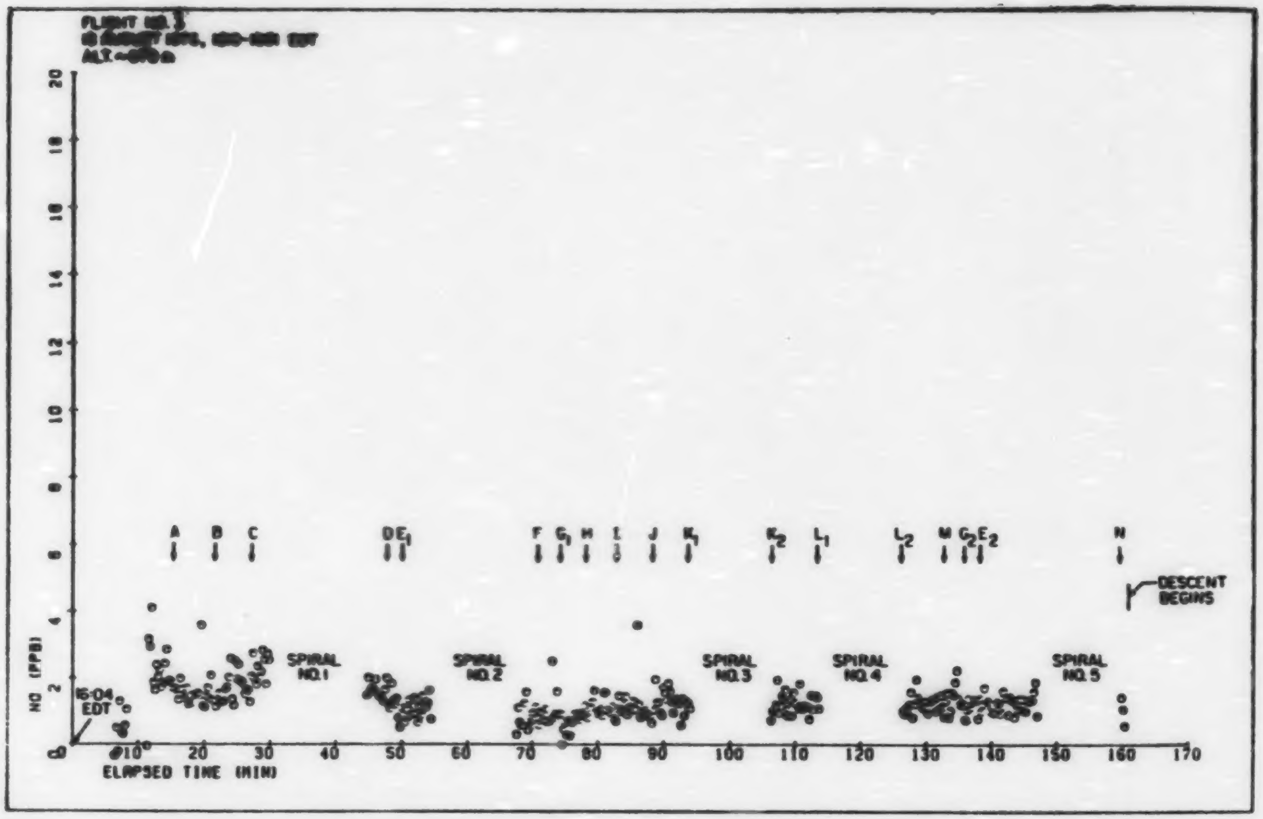


Figure F-3. Nitrogen oxide concentrations during horizontal sampling, Flight No. 3

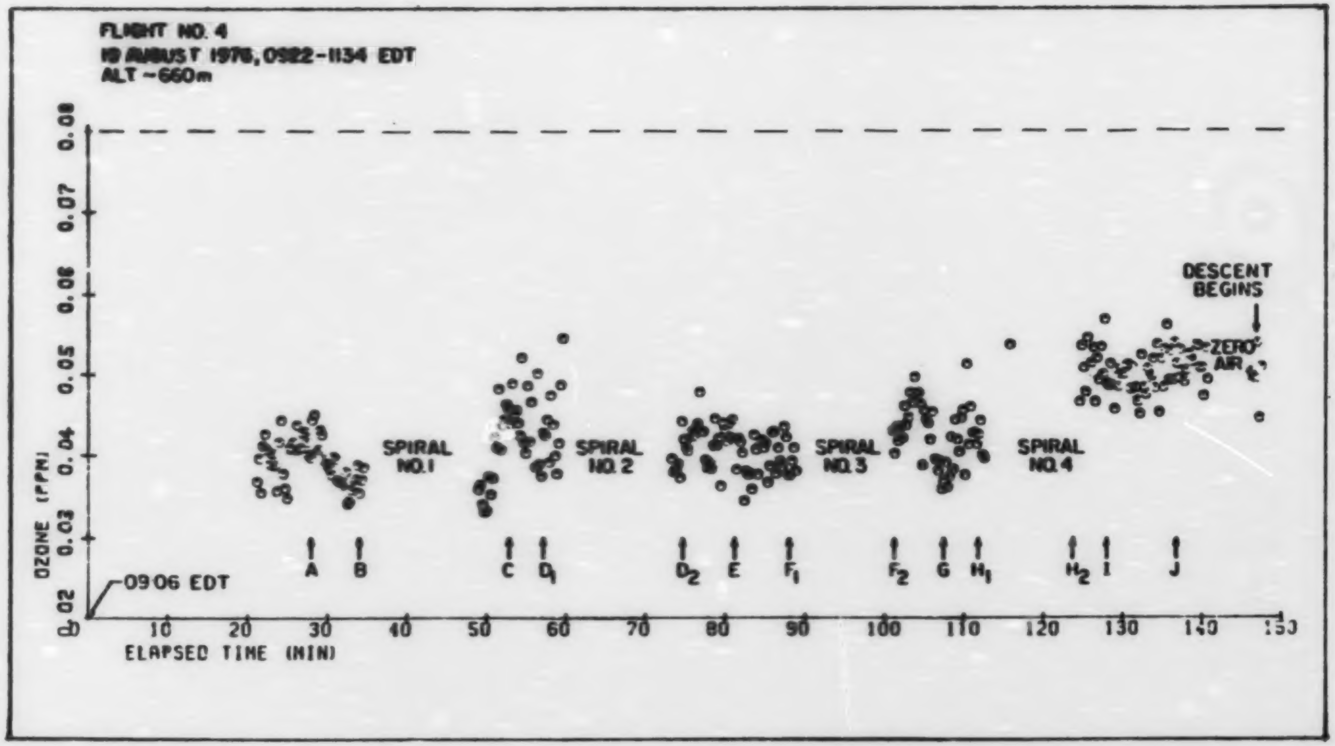


Figure F-4. Ozone concentrations during horizontal sampling, Flight No. 4

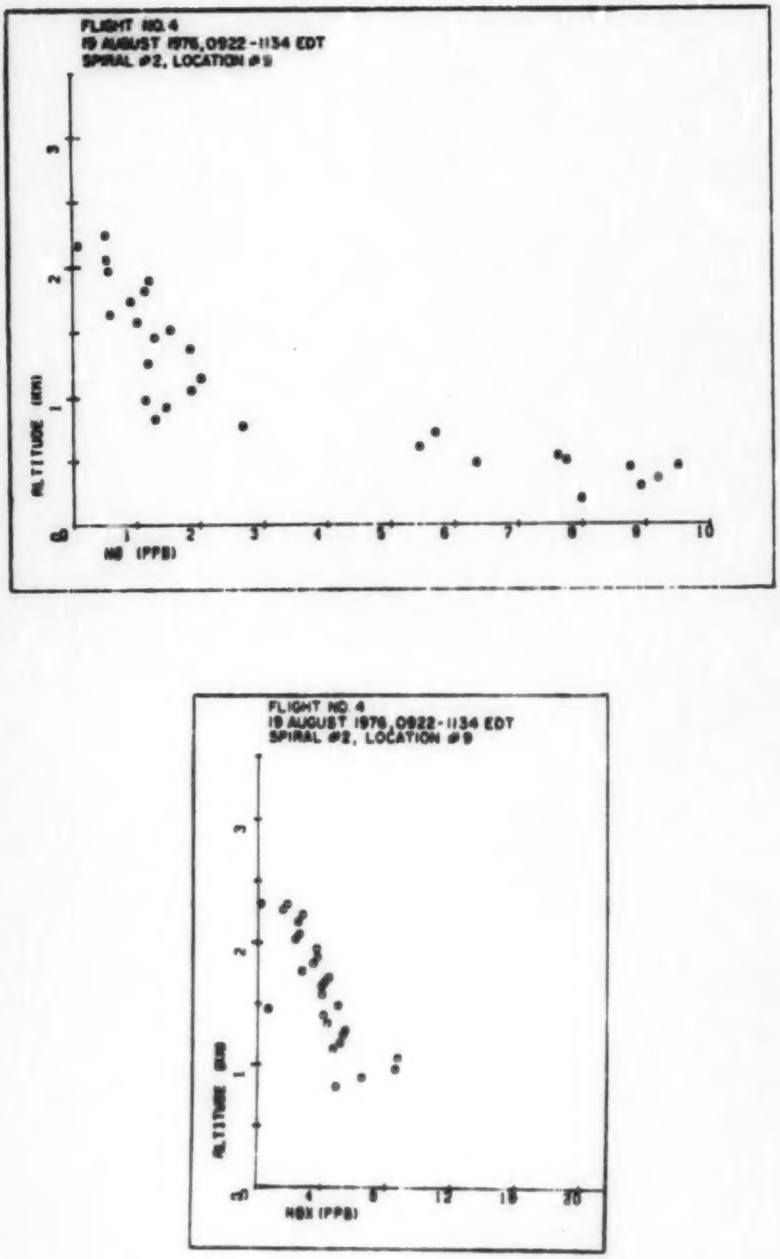


Figure F-5. NO and NO_x profiles, Flight No. 4

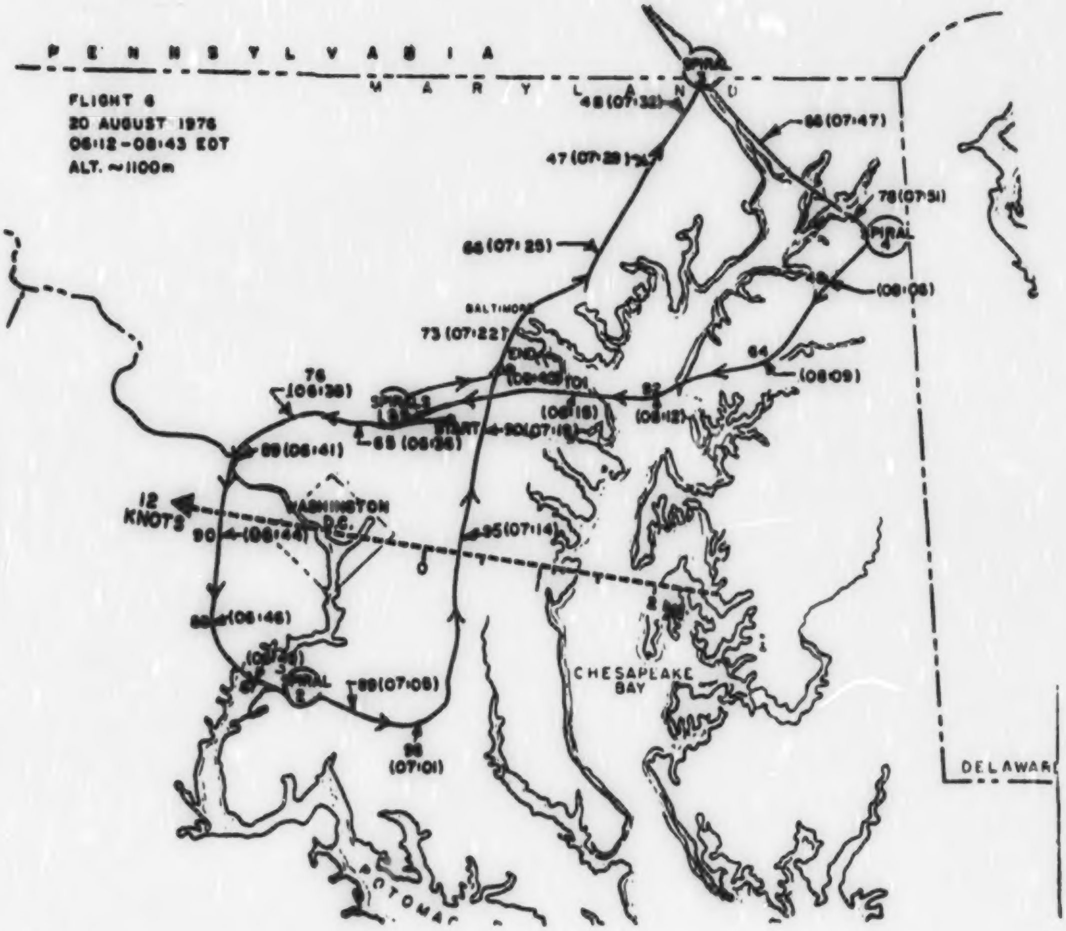

PENNSYLVANIA
MARYLAND
FLIGHT 6
20 AUGUST 1976
06:12-08:43 EDT
ALT. ~1100m
SPIRAL
48(07:32)
47(07:29)
66(07:25)
78(07:51)
SPIRAL 4
(08:06)
BALTIMORE
73(07:22)
END
64
(08:09)
76
(06:38)
SPIRAL 1
101
(06:15)
92
(06:12)
START
90(07:16)
65(06:36)
89(06:41)
12 KNOTS
WASHINGTON D.C.
90
(06:44)
95(07:14)
(06:46)
SPIRAL 2
89(07:05)
96
(07:01)
CHESAPEAKE BAY
DELAWARE
POTOMAC

Figure F-6. Sampling track during Flight No. 6. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow (Concentrations have not been adjusted for final calibration.)

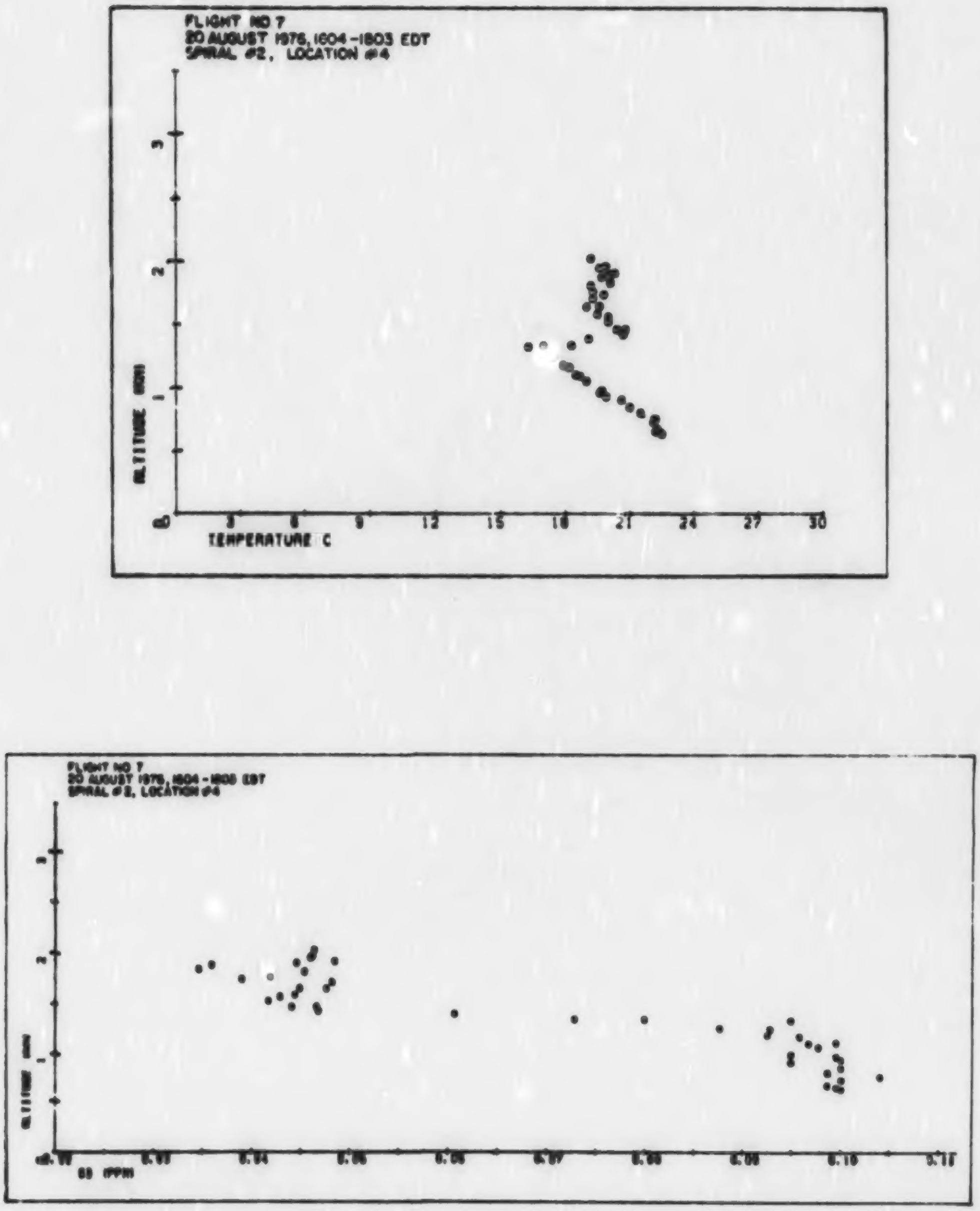


Figure F-7. Temperature and ozone profiles, Flight No. 7

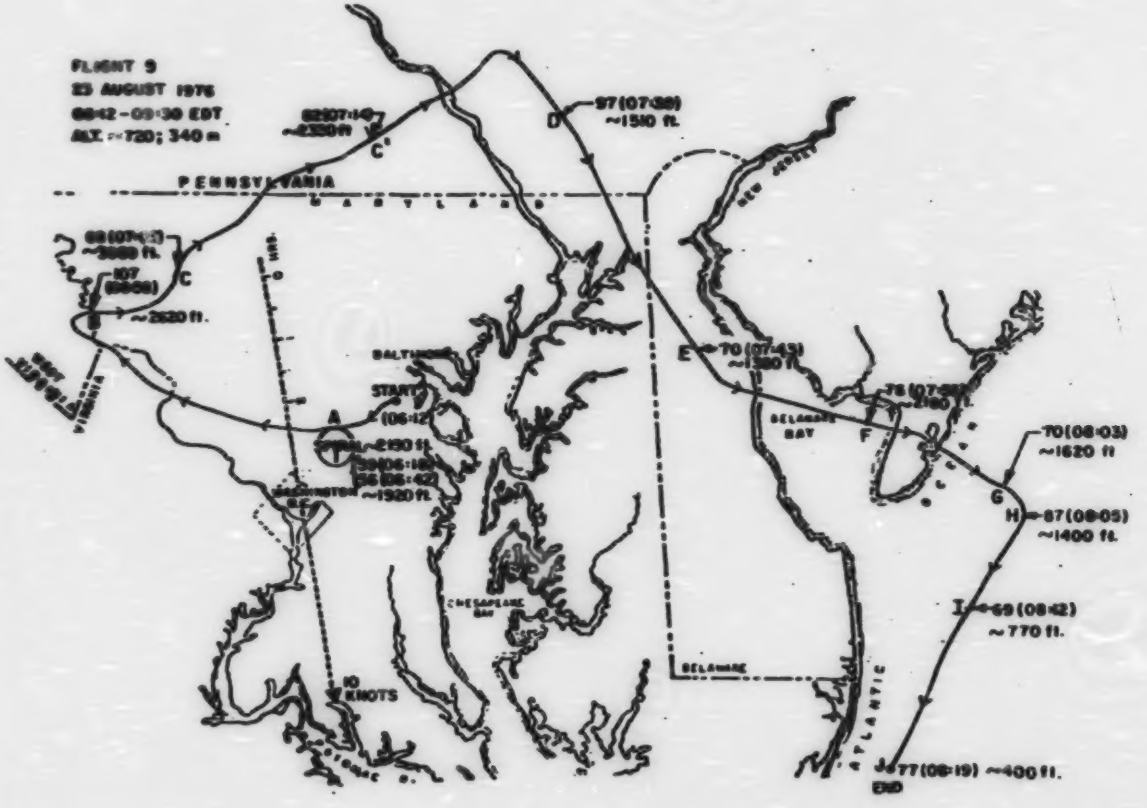

FLIGHT 9
25 AUGUST 1976
06:12-08:30 EDT
ALT. ~720; 340 m
PENNSYLVANIA
MARYLAND
NEW JERSEY
DELAWARE
DELAWARE BAY
CHESAPEAKE BAY
ATLANTIC
WEST VIRGINIA
VIRGINIA
BALTIMORE
START
WASHINGTON D.C.
(06:12)
~2130 ft.
59(06:18)
56(06:42)
~1920 ft.
A
107
~2620 ft.
C
88(07:12)
~3000 ft.
82(07:14)
~2350 ft
C'
D
97(07:39)
~1510 ft.
E
70(07:43)
~1380 ft.
F
76(07:5?)
~2160 ft.
G
70(08:03)
~1620 ft
H
87(08:05)
~1400 ft.
I
69(08:12)
~770 ft.
J
77(08:19) ~400 ft.
END
10 KNOTS
0

Figure F-8. Sampling track during Flight No. 9. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

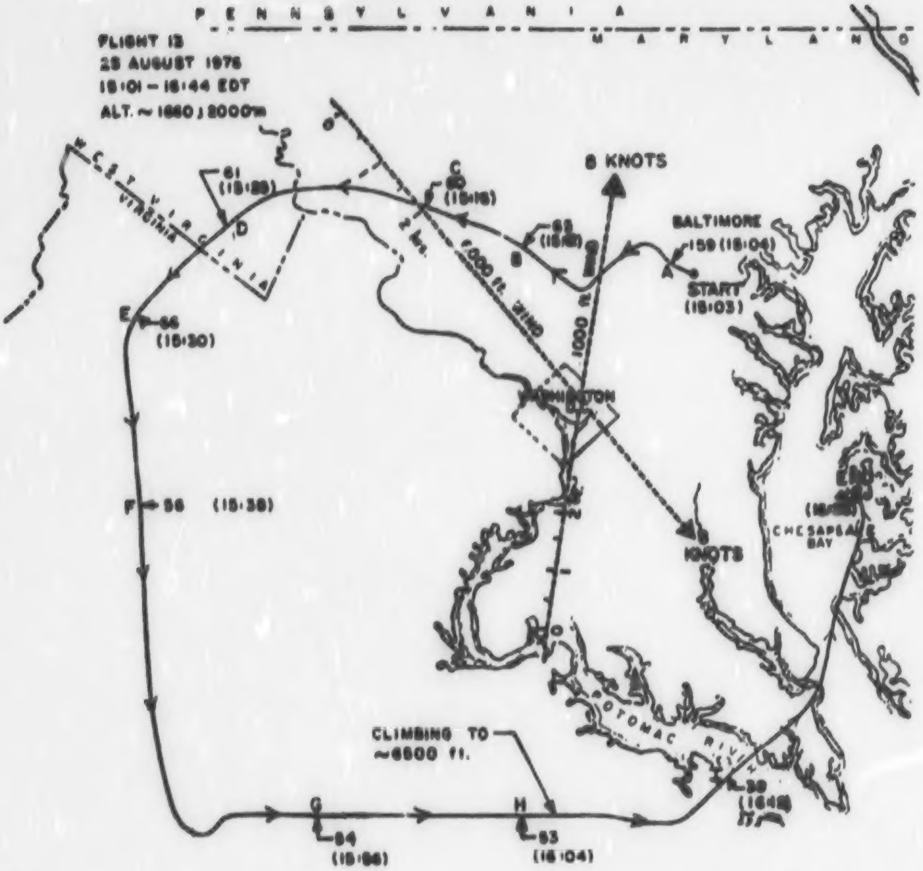

PENNSYLVANIA
MARYLAND
FLIGHT 13
25 AUGUST 1976
15:01 – 16:44 EDT
ALT. ~ 1660 ; 2000 m
WEST VIRGINIA
VIRGINIA
8 KNOTS
BALTIMORE
159 (15:04)
START
(15:03)
A
B
65
(15:10)
C
60
(15:16)
61
(15:23)
D
E
56
(15:30)
F
56
(15:38)
6000 ft. WIND
1000 ft. WIND
2 km
WASHINGTON
KNOTS
CHESAPEAKE BAY
POTOMAC RIVER
CLIMBING TO
~6500 ft.
G
54
(15:56)
H
53
(16:04)
39
(16:18)

Figure F-9. Sampling track during Flight No. 13. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Major wind shift with height is shown by transport winds at 1000 and 6000 feet

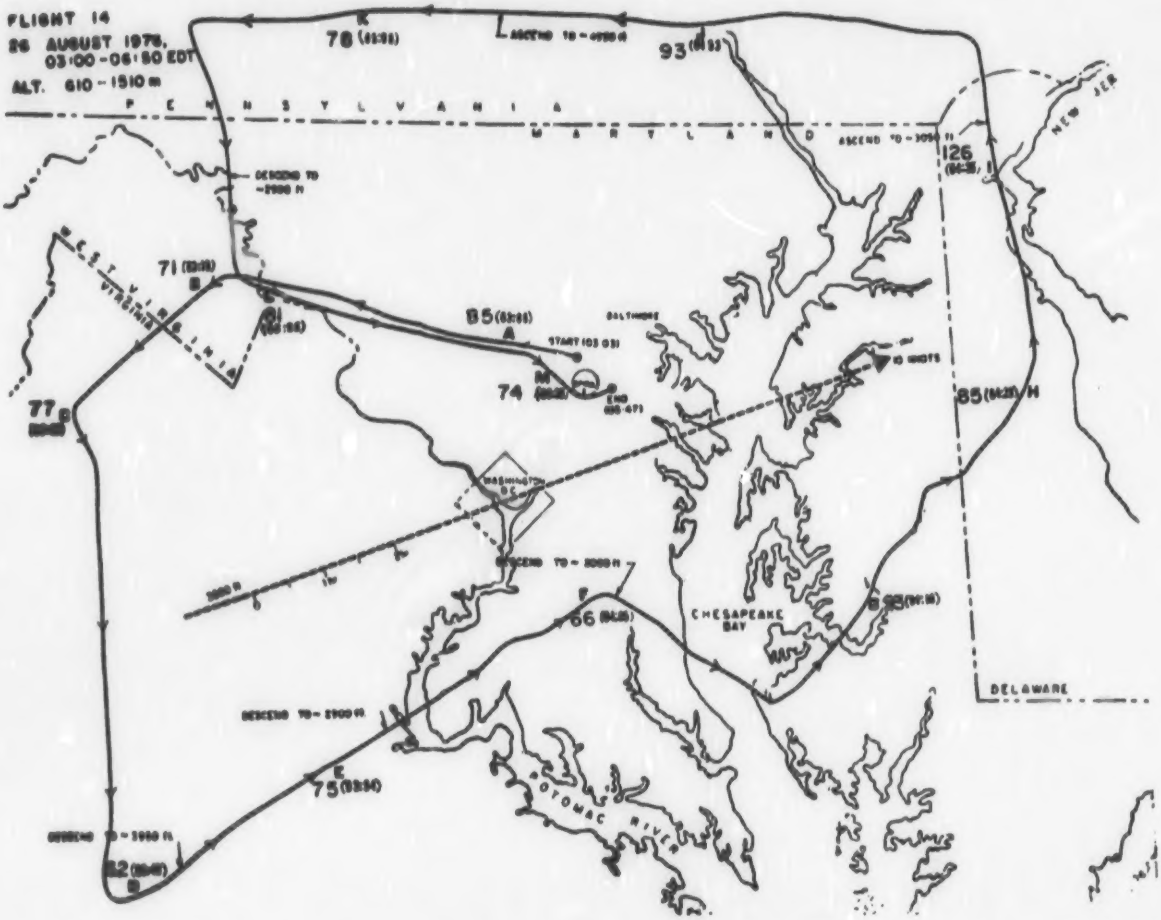

FLIGHT 14
26 AUGUST 1978,
03:00-06:50 EDT
ALT. 610-1510 m
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
NEW JER
DELAWARE
ASCEND TO -
78
K
93
126
I
85
H
DESCEND TO ~2900 ft
71
B
C
85
A
START (03 03)
74
M
END
BALTIMORE
10 KNOTS
77
D
WASHINGTON D.C.
DESCEND TO - 3000 ft
F
66
G
CHESAPEAKE BAY
DESCEND TO - 2900 ft
E
75
POTOMAC RIVER
DESCEND TO - 3000 ft
82
D

Figure F-10. Sampling track during Flight No. 14. Ozone concentration in ppb is shown at selected points, followed by time in parentheses. Transport wind at flight altitude is shown by dashed arrow

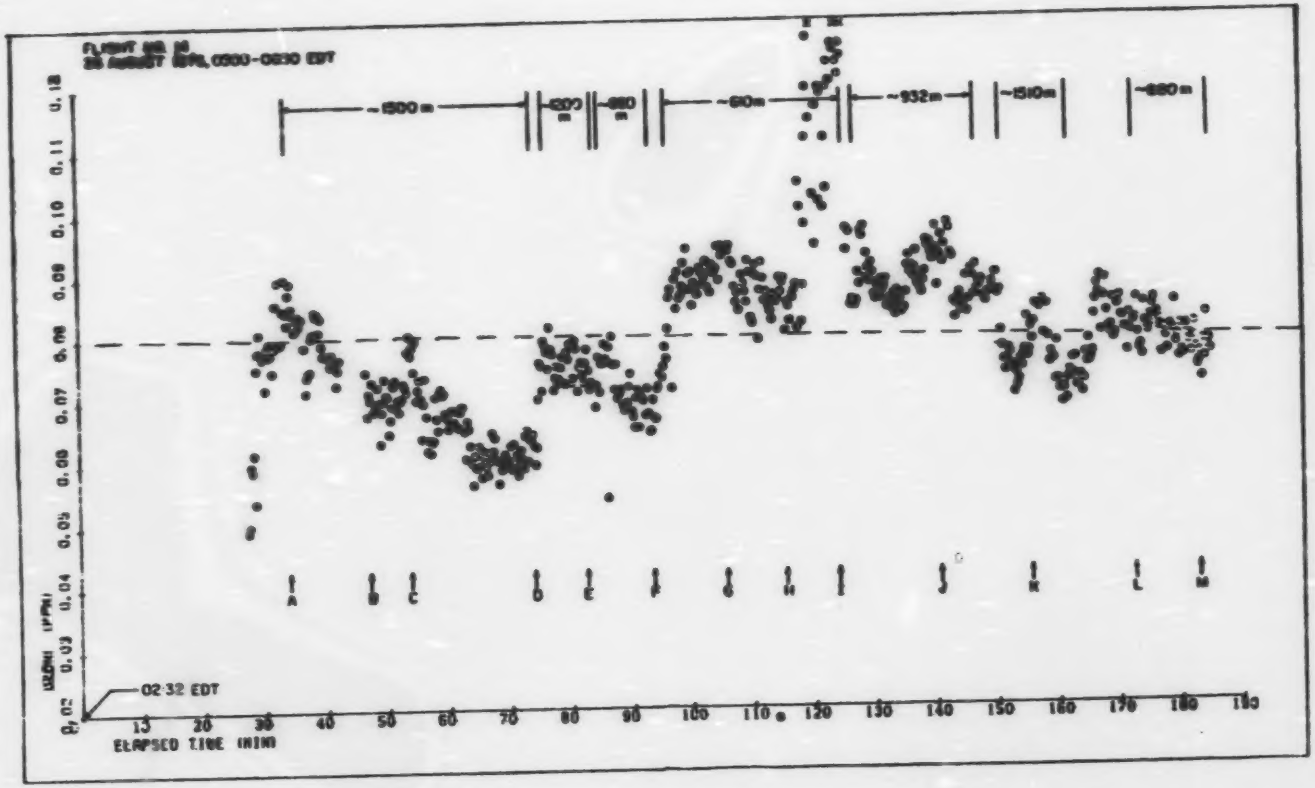


Figure F-11. Ozone concentrations during horizontal sampling, Flight No. 14

Table F-1. AVERAGE CONCENTRATIONS OF OZONE AND NITROGEN OXIDES WITHIN A 300 M DEEP LAYER (650-950 MSL) ABOVE STUDY AREA

Flight number	Date	Time, EDT	Spiral location	Concentration, ppb		
				O_3	NO	NO_x
1	8/17/77	11:00	1	38	–	–
2	8/18/77	09:12	2	42	3.6	–
		09:35	3	41	0.9	–
		10:01	4	42	2.5	–
		10:24	1	46	2.1	–
3	8/18/77	16:40	4	99	2.1	–
		17:05	1	94	1.0	–
		17:44	5	85	1.1	–
		18:04	6	99	1.2	–
		18:37	2	108	1.4	–
4	8/19/77	09:47	8	40	7.5	–
		10:11	9	52	3.0	8.0
		10:41	7	43	13.3	35.4
		11:05	10	45	8.8	21.4
5	8/19/77	16:18	8	76	2.1	9.1
		16:38	9	81	2.3	10.6
		17:04	7	101	4.5	32.2
		17:27	10	104	3.6	25.2
6	8/20/77	06:26	7	67	2.6	10.6
		06:51	4	70	–	16.5
		07:03	4[a]	78	1.4	14.4
7	8/20/77	16:15	7	118	8.0	46.4
		16:39	4	100	2.5	16.7
		17:20	9	91	2.1	14.2
		17:39	8	89	3.1	14.1
8	8/21/77[b]	12:01	7	87	1.4	5.5
		12:26	11	105	1.6	9.4
		12:44	12	94	0.25	3.6
		13:12	1	78	0.24	2.5
		13:38	13	113	(0.4)	4.0
9	8/23/77	06:28	7	64	0.06	1.3
10	8/23/77	16:28	7	64	0.05	1.2

[a] At ~1140 m

[b] Concentrations decrease rapidly with height

APPENDIX G

SUMMARY TABLES OF HYDROCARBON AND CARBON MONOXIDE DATA

(RTI Field Data Collected Daily
from 3 July 1976 Through
1 September 1976)

Table G-1. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR SUNDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.96	1.71	0.24	1.31	0.11	0.19	2.00
09-12 A.M.	1.88	1.54	0.34	1.10	0.15	0.40	2.52
12-03 P.M.	1.95	1.46	0.49	1.14	0.20	0.35	2.16
03-06 P.M.	1.64	1.39	0.25	0.84	0.13	0.59	2.94

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.80	1.67	1.13	1.07	0.38	1.03	2.66
09-12 A.M.	2.40	1.57	0.83	1.00	0.34	0.82	2.43
12-03 P.M.	2.30	1.50	0.80	0.97	0.35	0.91	2.60
03-06 P.M.	2.40	1.57	0.83	1.10	0.34	0.75	2.17

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.50	1.75	0.75	1.20	0.29	0.78	2.58
09-12 A.M.	2.42	1.57	0.85	1.08	0.34	0.89	2.46
12-03 P.M.	2.22	1.52	0.70	1.14	0.30	0.88	3.51
03-06 P.M.	2.30	1.52	1.00	1.06	0.45	2.00	3.35

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.15	1.65	0.50	0.65	0.19	1.18	6.61
09-12 A.M.	1.80	1.55	0.24	0.41	0.12	2.03	9.43
12-03 P.M.	1.73	1.53	0.20	0.50	0.09	0.35	6.43
03-06 P.M.	1.67	1.53	0.14	0.51	0.07	0.75	6.73

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.26	1.65	0.60	0.78	0.24	1.54	5.44
09-12 A.M.	2.10	1.62	0.48	0.75	0.20	0.68	3.72
12-03 P.M.	2.07	1.62	0.45	0.68	0.17	0.53	3.64
03-06 P.M.	1.87	1.60	0.27	0.85	0.14	0.39	2.86

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.10	1.70	0.40	1.02	0.17	1.01	4.14
09-12 A.M.	1.92	1.54	0.38	0.60	0.18	2.62	7.80
12-03 P.M.	1.53	1.49	0.04	0.66	0.02	0.02	3.04
03-06 P.M.	1.59	1.49	0.10	0.60	0.05	0.29	3.58

Table G-2. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR MONDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.25	1.71	0.54	2.76	0.22	0.18	0.85
09-12 A.M.	1.97	1.50	0.47	1.60	0.24	0.58	2.29
12-03 P.M.	1.93	1.50	0.43	1.69	0.19	0.23	1.20
03-06 P.M.	1.91	1.46	0.45	2.09	0.21	0.21	0.94

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.45	1.60	0.85	1.52	0.33	0.69	1.87
09-12 A.M.	2.38	1.67	0.70	2.72	0.29	0.38	1.31
12-03 P.M.	2.18	1.60	0.57	1.38	0.26	0.50	1.83
03-06 P.M.	2.87	1.52	1.35	2.07	0.46	0.82	1.72

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.67	1.63	1.03	2.17	0.38	0.56	1.38
09-12 A.M.	2.40	1.57	0.83	1.96	0.34	0.88	2.18
12-03 P.M.	2.30	1.56	0.74	1.70	0.31	0.56	1.88
03-06 P.M.	2.39	1.57	0.81	2.10	0.32	0.44	1.45

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.84	1.60	0.24	0.84	0.11	0.21	3.74
09-12 A.M.	1.85	1.55	0.30	0.64	0.14	0.48	4.06
12-03 P.M.	1.69	1.56	0.13	0.60	0.07	0.26	4.10
03-06 P.M.	1.80	1.57	0.23	0.73	0.10	0.19	3.64

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.12	1.75	0.37	1.37	0.17	0.27	1.66
09-12 A.M.	1.84	1.56	0.28	0.72	0.15	0.87	5.01
12-03 P.M.	2.02	1.60	0.42	1.02	0.19	0.38	2.23
03-06 P.M.	1.93	1.58	0.35	1.03	0.18	0.41	2.16

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.86	1.65	0.21	1.01	0.09	0.16	2.06
09-12 A.M.	1.67	1.51	0.16	0.79	0.08	0.17	2.63
12-03 P.M.	1.76	1.60	0.16	0.84	0.07	0.12	2.97
03-06 P.M.	1.70	1.50	0.20	0.74	0.09	0.23	2.65

Table G-3. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR TUESDAYS

SITE #16

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.25	1.60	0.65	2.84	0.28	0.23	0.84
09-12 A.M.	1.99	1.52	0.46	2.34	0.23	0.22	0.95
12-03 P.M.	2.01	1.50	0.51	2.15	0.24	0.23	1.01
03-06 P.M.	2.02	1.49	0.54	3.24	0.26	0.16	0.66

SITE #15

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.92	1.67	1.25	3.37	0.43	0.42	1.00
09-12 A.M.	2.59	1.55	1.03	2.08	0.38	0.57	1.48
12-03 P.M.	2.32	1.52	0.80	1.90	0.34	0.53	1.54
03-06 P.M.	2.25	1.45	0.80	1.63	0.34	0.50	1.48

SITE #4

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.89	1.65	1.24	2.26	0.42	0.78	1.77
09-12 A.M.	2.40	1.56	0.84	1.37	0.33	0.79	2.14
12-03 P.M.	2.29	1.53	0.76	1.11	0.33	0.76	2.26
03-06 P.M.	2.30	1.51	0.79	1.37	0.33	0.62	1.83

SITE #2

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.94	1.60	0.34	1.02	0.16	0.46	2.53
09-12 A.M.	1.80	1.54	0.26	0.77	0.13	0.67	4.05
12-03 P.M.	2.06	1.64	0.42	0.98	0.15	0.25	2.90
03-06 P.M.	1.90	1.57	0.33	0.82	0.15	0.79	4.40

SITE #12

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.17	1.66	0.51	1.34	0.23	0.60	2.20
09-12 A.M.	1.99	1.55	0.44	0.57	0.20	0.88	4.73
12-03 P.M.	1.81	1.53	0.29	0.63	0.14	0.62	5.38
03-06 P.M.	1.91	1.52	0.39	0.66	0.19	0.71	3.80

SITE #9

TIME INTERVAL	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.96	1.60	0.36	1.14	0.16	0.56	2.31
09-12 A.M.	1.80	1.51	0.29	1.01	0.13	0.32	2.17
12-03 P.M.	1.67	1.50	0.17	0.70	0.09	0.44	3.31
03-06 P.M.	1.65	1.50	0.15	0.74	0.07	0.31	3.00

Table G-4. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR WEDNESDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.19	1.64	0.54	2.63	0.24	0.30	1.54
09-12 A.M.	2.09	1.58	0.51	2.23	0.23	0.29	1.43
12-03 P.M.	1.97	1.50	0.47	2.09	0.23	0.26	1.08
03-06 P.M.	2.16	1.54	0.61	3.06	0.28	0.20	0.73

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.62	1.58	1.04	3.20	0.39	0.38	1.00
09-12 A.M.	2.58	1.56	1.02	2.24	0.38	0.46	1.24
12-03 P.M.	2.58	1.52	1.06	1.54	0.38	0.72	1.74
03-06 P.M.	2.52	1.50	1.02	2.16	0.39	0.49	1.24

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.87	1.59	1.29	2.46	0.38	0.54	1.27
09-12 A.M.	2.44	1.66	0.77	1.65	0.30	0.59	1.77
12-03 P.M.	2.39	1.49	0.90	1.00	0.36	1.02	2.64
03-06 P.M.	2.57	1.51	1.06	1.27	0.36	0.81	2.12

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.13	1.64	0.49	1.17	0.21	0.43	1.92
09-12 A.M.	1.81	1.56	0.25	0.74	0.13	0.73	4.01
12-03 P.M.	1.94	1.52	0.41	0.55	0.18	1.20	5.39
03-06 P.M.	1.92	1.52	0.40	0.62	0.18	0.82	4.00

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.21	1.72	0.49	1.47	0.20	0.35	1.79
09-12 A.M.	1.94	1.64	0.30	1.06	0.15	0.36	2.34
12-03 P.M.	1.88	1.57	0.31	0.66	0.16	0.64	3.68
03-06 P.M.	2.03	1.59	0.44	0.79	0.19	0.61	4.51

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.89	1.62	0.27	1.07	0.13	0.31	2.19
09-12 A.M.	1.84	1.50	0.34	0.74	0.16	0.85	3.95
12-03 P.M.	1.80	1.46	0.34	0.59	0.15	2.28	6.80
03-06 P.M.	1.86	1.49	0.37	0.76	0.15	0.72	3.14

Table G-5. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR THURSDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.60	1.66	0.94	3.29	0.33	0.28	0.80
09-12 A.M.	2.25	1.55	0.71	3.02	0.30	0.23	0.77
12-03 P.M.	2.27	1.57	0.70	2.80	0.29	0.29	0.88
03-06 P.M.	2.60	1.63	0.97	4.61	0.36	0.20	0.58

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.76	1.56	1.20	3.36	0.42	0.39	0.90
09-12 A.M.	2.62	1.50	1.12	2.36	0.42	0.54	1.25
12-03 P.M.	2.40	1.50	0.90	2.00	0.37	0.52	1.37
03-06 P.M.	2.38	1.57	0.80	3.42	0.33	0.31	0.87

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.47	1.60	0.87	1.74	0.30	0.52	1.72
09-12 A.M.	2.55	1.51	1.04	1.23	0.39	0.85	2.24
12-03 P.M.	2.34	1.50	0.84	1.34	0.34	0.77	2.13
03-06 P.M.	2.24	1.50	0.74	1.69	0.31	0.47	1.57

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.24	1.59	0.66	0.97	0.24	0.57	2.35
09-12 A.M.	2.12	1.60	0.52	0.78	0.19	0.61	3.25
12-03 P.M.	1.97	1.63	0.34	0.71	0.14	0.55	3.87
03-06 P.M.	1.77	1.54	0.23	0.81	0.12	0.33	2.87

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.01	1.60	0.41	1.04	0.19	0.41	2.33
09-12 A.M.	1.89	1.65	0.24	0.81	0.12	0.35	2.77
12-03 P.M.	1.93	1.54	0.39	0.69	0.18	0.47	3.08
03-06 P.M.	2.06	1.64	0.41	0.90	0.17	0.41	2.59

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.00	1.68	0.32	1.15	0.14	0.32	1.98
09-12 A.M.	1.79	1.52	0.27	1.03	0.14	0.28	1.96
12-03 P.M.	1.70	1.60	0.10	0.86	0.05	0.09	2.33
03-06 P.M.	1.63	1.50	0.13	0.90	0.07	0.12	2.20

Table G-6. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR FRIDAYS

SITE #16	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.37	1.64	0.73	3.63	0.30	0.20	0.58
09-12 A.M.	2.30	1.61	0.69	3.20	0.30	0.24	0.79
12-03 P.M.	2.02	1.51	0.51	2.34	0.25	0.33	1.28
03-06 P.M.	2.55	1.86	0.69	4.01	0.29	0.18	0.89

SITE #15	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.65	1.75	0.90	3.67	0.33	0.25	0.74
09-12 A.M.	2.18	1.52	0.65	2.82	0.30	0.24	0.82
12-03 P.M.	2.12	1.47	0.65	1.57	0.30	0.42	1.39
03-06 P.M.	3.50	1.75	1.75	3.20	0.49	0.54	1.11

SITE #4	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.63	1.77	0.86	2.53	0.31	0.42	1.34
09-12 A.M.	2.16	1.66	0.50	1.20	0.21	0.43	2.01
12-03 P.M.	2.32	1.56	0.76	1.30	0.29	0.54	2.02
03-06 P.M.	2.27	1.70	0.58	1.52	0.22	0.36	1.53

SITE #2	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.96	1.63	0.33	1.07	0.15	0.31	2.15
09-12 A.M.	1.80	1.56	0.24	0.61	0.12	0.51	4.92
12-03 P.M.	1.90	1.60	0.30	0.83	0.14	1.31	5.48
03-06 P.M.	1.77	1.53	0.23	0.82	0.12	0.53	3.22

SITE #12	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.20	1.68	0.52	1.48	0.23	0.39	1.73
09-12 A.M.	2.03	1.66	0.37	1.00	0.17	0.41	2.68
12-03 P.M.	2.05	1.67	0.38	0.92	0.18	1.12	4.99
03-06 P.M.	2.13	1.75	0.38	1.12	0.17	0.55	2.47

SITE #9	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.89	1.64	0.25	1.07	0.12	0.29	2.26
09-12 A.M.	1.71	1.55	0.16	1.14	0.09	0.34	3.16
12-03 P.M.	1.63	1.54	0.09	0.79	0.05	0.07	3.97
03-06 P.M.	1.71	1.54	0.17	1.14	0.10	0.23	2.10

Table G-7. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR SATURDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.07	1.59	0.49	1.87	0.23	0.38	1.55
09-12 A.M.	2.11	1.63	0.49	1.90	0.22	0.40	1.57
12-03 P.M.	1.95	1.58	0.37	1.60	0.18	0.35	1.68
03-06 P.M.	1.87	1.54	0.33	1.50	0.17	0.33	1.62

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.93	1.90	1.03	2.13	0.35	0.48	1.39
09-12 A.M.	3.80	1.80	2.00	1.97	0.51	1.01	1.96
12-03 P.M.	2.23	1.73	0.50	1.90	0.22	0.29	1.23
03-06 P.M.	2.63	1.53	1.10	1.57	0.40	0.77	1.82

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.45	1.75	0.70	1.75	0.27	0.86	2.32
09-12 A.M.	2.72	1.65	1.07	1.32	0.36	1.11	2.62
12-03 P.M.	2.57	1.60	0.97	1.22	0.36	1.07	2.58
03-06 P.M.	2.45	1.57	0.88	0.98	0.35	1.62	4.24

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.86	1.65	0.21	0.65	0.10	1.06	5.89
09-12 A.M.	1.81	1.52	0.29	0.52	0.15	1.18	6.15
12-03 P.M.	1.75	1.57	0.18	0.50	0.09	1.40	6.92
03-06 P.M.	1.83	1.57	0.27	0.55	0.12	1.48	6.45

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.30	1.99	0.31	1.39	0.14	0.39	2.51
09-12 A.M.	2.00	1.61	0.39	0.77	0.19	1.30	4.54
12-03 P.M.	1.97	1.55	0.42	0.72	0.20	1.65	5.66
03-06 P.M.	2.30	1.56	0.74	0.86	0.23	0.99	4.79

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.04	1.73	0.31	0.93	0.14	1.45	5.97
09-12 A.M.	1.80	1.47	0.33	0.90	0.15	1.28	4.91
12-03 P.M.	1.67	1.54	0.13	0.77	0.07	0.36	3.99
03-06 P.M.	1.67	1.56	0.11	0.81	0.05	0.35	3.96

Table G-8. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR WEEKDAYS

SITE #16

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.33	1.65	0.67	3.00	0.27	0.24	0.96
09-12 A.M.	2.12	1.55	0.57	2.49	0.25	0.30	1.22
12-03 P.M.	2.05	1.52	0.53	2.24	0.24	0.27	1.09
03-06 P.M.	2.25	1.60	0.65	3.43	0.28	0.19	0.75

SITE #15

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.70	1.63	1.07	3.07	0.38	0.42	1.08
09-12 A.M.	2.49	1.56	0.93	2.40	0.36	0.45	1.24
12-03 P.M.	2.33	1.52	0.81	1.69	0.33	0.55	1.58
03-06 P.M.	2.60	1.53	1.07	2.31	0.40	0.55	1.35

SITE #4

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.71	1.65	1.06	2.22	0.36	0.57	1.52
09-12 A.M.	2.41	1.59	0.81	1.50	0.32	0.72	2.06
12-03 P.M.	2.33	1.52	0.80	1.29	0.33	0.74	2.20
03-06 P.M.	2.36	1.55	0.82	1.60	0.32	0.56	1.71

SITE #2

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.01	1.61	0.40	1.01	0.17	0.39	2.57
09-12 A.M.	1.86	1.56	0.30	0.71	0.14	0.60	4.10
12-03 P.M.	1.90	1.58	0.32	0.71	0.14	0.74	4.43
03-06 P.M.	1.84	1.55	0.29	0.75	0.14	0.53	3.63

SITE #12

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.15	1.69	0.45	1.34	0.20	0.41	1.96
09-12 A.M.	1.94	1.62	0.33	0.84	0.16	0.56	3.40
12-03 P.M.	1.93	1.59	0.35	0.76	0.17	0.65	3.93
03-06 P.M.	2.01	1.61	0.40	0.88	0.18	0.55	3.25

SITE #9

	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.92	1.64	0.28	1.08	0.13	0.33	2.17
09-12 A.M.	1.76	1.52	0.24	0.94	0.12	0.40	2.81
12-03 P.M.	1.71	1.54	0.18	0.75	0.08	0.63	3.97
03-06 P.M.	1.71	1.51	0.21	0.85	0.10	0.33	2.54

Table G-9. SUMMARY OF HYDROCARBON AND CARBON MONOXIDE DATA FOR ALL DAYS

SITE #16	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.25	1.65	0.59	2.64	0.25	0.25	1.17
09-12 A.M.	2.09	1.55	0.53	2.22	0.24	0.33	1.46
12-03 P.M.	2.02	1.52	0.51	2.00	0.23	0.29	1.32
03-06 P.M.	2.13	1.55	0.56	2.84	0.25	0.26	1.15

SITE #15	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.73	1.66	1.07	2.78	0.38	0.49	1.27
09-12 A.M.	2.61	1.58	1.03	2.22	0.37	0.55	1.43
12-03 P.M.	2.32	1.54	0.78	1.64	0.32	0.56	1.65
03-06 P.M.	2.58	1.53	1.05	2.11	0.39	0.59	1.48

SITE #4	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.65	1.67	0.97	2.03	0.34	0.63	1.75
09-12 A.M.	2.45	1.60	0.85	1.42	0.33	0.79	2.19
12-03 P.M.	2.35	1.53	0.81	1.26	0.33	0.80	2.40
03-06 P.M.	2.37	1.55	0.85	1.45	0.34	0.87	2.26

SITE #2	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.01	1.62	0.39	0.90	0.16	0.61	3.48
09-12 A.M.	1.84	1.55	0.29	0.64	0.14	0.88	5.13
12-03 P.M.	1.86	1.57	0.28	0.65	0.12	0.77	5.06
03-06 P.M.	1.81	1.55	0.26	0.69	0.12	0.69	4.45

SITE #12	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	2.19	1.72	0.47	1.25	0.20	0.61	2.65
09-12 A.M.	1.97	1.62	0.35	0.92	0.17	0.68	3.60
12-03 P.M.	1.95	1.58	0.37	0.74	0.17	0.76	4.12
03-06 P.M.	2.04	1.60	0.44	0.87	0.18	0.60	3.45

SITE #9	AVERAGE CONCENTRATION (PPM)				AVERAGE RATIO		
TIME INTERVAL	THC	CH4	NMHC	CO	NMHC/THC	NMHC/CO	THC/CO
06-09 A.M.	1.95	1.66	0.30	1.06	0.14	0.56	2.91
09-12 A.M.	1.78	1.51	0.27	0.90	0.13	0.74	3.60
12-03 P.M.	1.68	1.53	0.15	0.74	0.07	0.50	3.83
03-06 P.M.	1.69	1.51	0.18	0.81	0.09	0.33	2.95